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ON THE DEPENDENCE OF WHAT APPARENTLY TAKES PLACE IN NATURE UPON WHAT ACTUALLY OCCURS IN THE UNIVERSE OF REAL EXISTENCES.

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CHAPTER I. INTRODUCTION.

Hitherto attempts to ascertain the events that are actually happening in the universe of real existences, and to ascertain what those existences are—in other words, the study of ontology—have been pursued almost exclusively from the standpoint of the metaphysician of the human mind. This mode of treatment has led to a few negative results which are chiefly of value by helping to dispel some popular errors, but it has established little that is positive, or that can be of service to the scientific student of nature. And yet investigations of Natural Science have been pushed in more than one direction into contact with problems of ontology, and are there brought to a stand owing to the different levels at which these two fields of investigation lie. Examples of this are met with in physiology, when we find our progress blocked on coming face to face with the problem as to what is the true nature of the interdependence between the thoughts of animals and changes in their brains; and generally throughout physics, when we make any attempt to penetrate to the causes of the events that occur. It appears, therefore, to be in an eminent degree desirable that an attempt shall be made to bring natural science and ontology into line by carrying on the ontological investigation from the standpoint of the scientific student of nature.

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There are other reasons also why the inquiry should be taken up by scientific men. The difficulties which have to be encountered are perhaps not so much intrinsic as collateral. They all arise from the circumstances under which we, men, have to carry out the inquiry, and are of a kind with which scientific men are better fitted to cope than others. A very serious liability to error is consequent upon the excessively secluded position of the human mind in the universe of existing things. How indirect and how slender the connections will appear in the sequel. This creates illusions greater than those experienced by the old astronomers who were misled by man's being tied to an earth that seemed to them to be stationary. Another chief source of our difficulties is that we have to enter on this study hampered by crude beliefs in which we have been brought up, which are embedded into the language we are obliged to use, and in which we habitually think; but which the inquiry shows to be a jumble of truth and error. These we must make it our business to correct, retaining the germ of truth in each, and by slow degrees acquiring the power of amending, promptly and without effort, all those parts of these beliefs which require correction. We are far from having done enough when we merely become aware of the errors; nor is it even enough that we shall have discovered what ought to take their place. We have not accomplished our task till it becomes our second nature to do this habitually and without premeditation, with regard to all that is about us and all that is within us. This takes time. But when it is accomplished the reward is great. A special difficulty arises from our being obliged to use some one of the languages that can be understood by our fellow-men. Every language that has been devised by man implies mistaken views in ontology; and that not occasionally, for every human language is permeated by these errors.

Now, students of natural science, men who have had an extensive training in the study of nature, and especially those who have devoted themselves mainly to the dynamical and physical aspects of that study, are better equipped for contending successfully with these difficulties than are their fellow-students whose main training has been confined to the tiny plot which lies within the ring-fence that surrounds the works of man—the languages he has devised, his literature and history, his music, poetry, architecture, painting and sculpture, his jurisprudence, his moral relations, the metaphysics of his mind, and so on; in fact, all branches of what in our universi-

ties are called the humanities. Explorers of nature, investigators of the work done or being done *which is not man's work*, stand a better chance of success than those whose thoughts mainly travel within the narrower range: and on several accounts; first, because they find less difficulty in freeing themselves from the limitations of the human standpoint, which we may liken to the Ptolemaic point of view, and in grasping the wider resources of a more Copernican survey; largely, too, because they more easily become expert in using such symbols as words in a generalized or otherwise modified sense when it becomes necessary to do so; but perhaps most of all because they are already familiar with the contrast between the two kinds of supposition which those physicists who use language carefully distinguish as *theories* and *hypotheses*. As some readers of the papers I have already written on these subjects have found here their chief difficulty, it appears desirable to devote a chapter of this essay to its elucidation. This, indeed, is almost necessary; inasmuch as sound progress in the task before us is not even possible unless this distinction is clearly grasped, and unless a facility has been acquired in handling both hypotheses and theories without risk of the confusion between them which has been too often made.

Chapter 2. Of Theories and Hypotheses.

Both theories and hypotheses are suppositions—a theory means a supposition which we hope to be true, a hypothesis is a supposition which we expect to be useful. Theories accordingly are either correct or incorrect, true or false, quite irrespectively of whether we, men, can make much, or little, or any use of them. *The merit of a theory is simply to be true.* It often, indeed usually, happens that the true theory is also useful; but it by no means need be so. Accordingly, the question whether a particular theory is of any use is irrelevant.

On the other hand a hypothesis is a supposition which aims at being useful, and *which is legitimate if useful.* A hypothesis may be a theory—in other words, a supposition which we make expecting it to help us forward in our investigation, may also be the supposition which we think to be true: but it by no means need be so; and in fact the best, *i.e.*, the most useful, hypotheses are often of the kind that make no pretense to being true. For example, all applications of mathematics to the investigation of nature are de-

ductions from data, in which simpler machinery is intentionally substituted for complex operations going on in objective nature. Thus, in computing the mutual perturbations of the planets, the planets are treated as though they were spheres, made up of untextured spherical shells, each of uniform density throughout; and it is left out of account that they approach to being spheroids, with mountains on their surface, irregularities of a like kind at greater depths, rocks in those mountains, minerals in those rocks, a different molecular texture in each mineral involving numberless motions among and within the molecules; moreover with tidal strains, heat expansions by day, contractions by night, and so on; perhaps seas and an atmosphere, vegetation and animals, all in constant and complicated movement; with a multitude of other details. Now it is legitimate to omit all these from our calculation, for though every one of them produces its effect in actual nature, the difference between their joint operation and that computed from the immensely simplified hypothesis made by the mathematician, can be shown to be too small to make any approach to being detected by any human appliance. Hence, for any purpose which is of use to man, the approximation arrived at by the simpler problem is sufficient, wherever the errors are of such a nature that they are not cumulative. *Nevertheless, it should be clearly recognized that it is a model of nature—a mechanism illustrating nature—and not nature itself, that has been mathematically investigated.*[1] So it is with all dynamical

[1] This has been sometimes overlooked. A recent instance is in a determination of the rate at which gases escape from atmospheres, based on the insufficient data commonly used in the mathematical investigation of such problems, and leading to a rate for the escape of helium from the earth's atmosphere which is negatived by observation (see Bryan, on the Kinetic Theory of Atmospheres, *Phil. Trans. of the Royal Society*, vol. 196 A, 1901, p. 1; and Stoney, on the behavior of helium in the earth's atmosphere, *Astrophysical Journal*, vol. xi, 1900, p. 369).

In such cases it may be difficult, and is sometimes impossible, to put our finger on the oversight that has been made. In this instance it may be conjectured with some probability that the mistake has been in the tacit assumption that the partition of energy between the internal and the translational motions of the molecules takes place with a frequency which warrants our arguing from the supposition, tacitly made in the mathematical investigation, that it goes on without intermission. There seems reason to believe that this partition of energy actually takes place, not at every encounter, but only at encounters as infrequent from the molecular standpoint as those that make chemical reaction possible between the molecules of a mixture of suitable gases. Now this, in the case of a mixture

investigations: the data of nature are loaded with minute detail and are far too much involved; they have to be simplified to bring the task within the range of man's power over mathematical analysis.

But for our present purpose a specially instructive instance is found in Geometrical Optics. The correct objective theory of light appears to be that light consists objectively of waves of alternating electro-magnetic stresses advancing through the ether. Now the whole of Geometrical Optics—which is one of our most useful sciences—is built upon the supposition that light consists of rays—a supposition which must not be mistaken for a *theory* of light: on the contrary, this supposition is to be employed as a useful and therefore legitimate *hypothesis*. In Geometrical Optics what we investigate is the succession of events, not in nature, but in a model of nature. We have substituted a model which contains far more easily handled machinery than that which operates in nature, every step in the progress of which can be foretold by the application of singularly easy mathematical analysis, can be represented in easily understood diagrams, and can be imagined and followed without difficulty by students who possess but little skill. What a loss we should sustain if that most useful hypothesis were not available! the justification of which is that it is so easily dealt with, and that it furnishes results that are true within known limits. For example, the new machinery furnishes the correct positions of optical images, although the image itself, the geometrical image as it is called, differs in material respects from any real image. Thus, it presents us with an unlimited amount of detail, much of which must be regarded as false, because it is detail which does not exist in the images produced by nature. The hypothesis is useful *within* certain limits, but will mislead if misapplied.

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of equal volumes of hydrogen and chlorine, only occurs about once in 1000 million encounters in sunshine, and less frequently in feebler light, down to about once in 100 millions of millions of encounters, so far as the observations have been recorded. An infrequency of this kind would have but little effect at the bottom of our atmosphere, but would make the distribution of molecular speeds differ altogether from that which has been computed in that penultimate stratum of the earth's atmosphere from which the escape takes place.

Chapter 3. Of the Absolute and Relative Significations of Terms.

We may make use of Geometrical Optics for another purpose—to illustrate the variety of meanings which such words as existence, theory, hypothesis, actual, real, etc., may have. They are freely used in Geometrical Optics. They are there used in a *relative* sense, in subordination to the hypothesis that light consists of rays, which for the time being must be left unquestioned, and which we may call the master hypothesis, as it governs the use to be made of those terms. Thus we speak of *real* rays in front of a mirror, and of *virtual* rays behind it; we say that the true *theory* is that the image on the retina is formed by rays reflected from the front of the mirror, but that it is legitimate to make the *hypothesis* that they emanate from a virtual image behind. When, however, we take the wider view that light is an electro-magnetic *undulation*, we recognize that what a moment ago we called real rays are not real, but a machinery substituted for what is real in the new sense that we have now to give to that word. For we are now using the term *real* in subordination to a much wider hypothesis, viz.: the great objective hypothesis that not only do our perceptions exist temporarily, but also that each of those *syntheta of perceptions* which we call natural objects exists as a whole and persistently. And when we come in turn to recognize that this, in its turn, is not the true theory of existence, but only an eminently useful hypothesis—probably, indeed, the most useful hypothesis known to man—and when we find that we must advance a step behind it to reach the true theory of existence, then at last we reach the stage at which we may use the word *real* in its fullest *absolute* sense; if we succeed in acquiring a right to apply it to what is going on in the autic universe, the universe of real existences. Thus such terms as existence, theory, real, actual, etc., only attain their absolute, which is their fullest, meaning when applied to the events that go on in the Universe of Auta; and are to be understood in their objective, which is a relative, sense when applied to what we regard as going on in that great objective hypotheton which we call nature; and in another still more removed relative sense when used in subordination to the narrower hypothesis which we have to entertain while investigating nature by the science of Geometrical Optics. When once this is clearly understood we are warned, and in some degree forearmed,

against falling into mistakes between the various shades of meaning which the poverty of language obliges us to put up with in such terms as existence, theory, actual, real, etc. If in any context we have occasion to employ any of these terms in more than one of its permissible meanings, it may sometimes be advisable to distinguish between them in some such way as that which is familiar to mathematicians when they write a, a', a'', etc., for different quantities. Availing ourselves of this device, we may write [real], within square brackets, when we wish to make it explicit that the word is to be understood in its absolute, that is in its autic, sense; and [real]′, with a dash, when the word is used in its objective, which is it principal relative, sense; while [real]″, [real]‴, etc., may be used to signify the other relative meanings which the term has when used in subordination to more limited hypotheses, as when we describe the rays of Geometrical Optics as being some of them [real]″ and others virtual. The same treatment may be extended to any other terms that seem to require the precaution. It is against mistakes between the *objective* and the *autic* significations of words that we have to be most on our guard. This will become clearer as we proceed.

Chapter 4. Of Auta: and of the Meaning to be Attributed to the Word *totality*.

It may be seen from the foregoing pages that the human mind is better fitted to cope with the scientific study of what apparently occurs in nature, than with the attempt to penetrate behind nature to the causes of these appearances. To do this requires us to inquire what has been happening in the universe of real existences, and to endeavor to determine what those existences are.

In the scientific study of nature we travel along one of the great *highways* of human thought; in ontology we have to make our roads as well as to push our way along them. It is therefore all the more important that we should bring to our aid every help which the scientific study of nature can supply. The present essay is an attempt to avail ourselves of this assistance.

Let us for convenience call the real existences *auta* (*τά ὄντα αὐτά*) —the very things themselves. An auto, then, is a thing that really exists, and in no wise depends on the way we—human minds—may happen to regard it. Our impressions or beliefs about it may be correct or may be erroneous, but the term auto means the thing *itself*.

We may also use the term *universe* to mean the *totality* of these auta. To prevent confusion, it may be well to designate the totality of natural objects by some other name. We may call it *nature*, or *the cosmos*, reserving the term universe for *the totality of auta*. Or, if at any time the word *universe* is applied to the totality of natural objects, it may be written with a dash, the objective [universe]′, to distinguish it unmistakably from the autic [universe]. It is to be noted that here and elsewhere the word *totality* is to be understood as having a more comprehensive[1] meaning than the word aggregate. Any collection of auta, however disorderly, would be an aggregate of those auta. By their *totality* is to be understood those auta, *under one definite set of conditions*—viz.: under the conditions that actually prevail—with those mutual relations, performing those operations, undergoing those changes that actually occur.

Chapter 5. In what Sense the Term *thought* is Employed.

We shall want a term which is applicable to *everything* of which I or my fellow-men or the lower animals can be conscious; and as at present no word in the English language has this wide signification, we shall extend or generalize the meaning of the term *thought*, so as to make it serve. Accordingly *thought*, in the generalized sense in which we shall use it, embraces sensations, perceptions, beliefs, feelings, memories, emotions, sentiments, judgments, motives, acts of will, and so on—in fact, everything which comes within the consciousness of any animal. I shall also use the term *I*, or *the ego*, or *my mind*, to denote the totality (not the mere aggregate) of a certain group of these thoughts, which may be spoken of as *my* thoughts. Observe that the word mind is here used in one of the two significations which it has in the English language, and that it will not in the present essay be used in the other of those senses. Accordingly, in the present essay, the term *mind* will not be used to signify the 'spiritual substance' which, according to a view very widely entertained, is supposed to be in existence, as well as the

[1] In Formal Logic the *comprehension* of a term is *the collection of ideas* which are included in the definition of the term. Accordingly, the greater the comprehension of a term, the fewer will be the individuals to whom that term can be applied. This is expressed in Logic by saying that the greater the *comprehension* of a term, the less is its *extension*. For example, Spaniard is a term which has a greater comprehension and a less extension than European.

thoughts. This supposed existence, if there is occasion to speak of it, will be called the man's spirit; but his *mind*, at a given time, will mean simply *the totality of a certain definite group of thoughts* at that time.

Chapter 6. The Postulates of the Present Inquiry.

We are now in a position to present a list of the postulates upon which our further progress will be built. Almost all men are agreed that these beliefs are fundamental, and most men would add considerably to the list. The very short list here set forth has been obtained by excluding from the longer list all that on trial were found not to be necessary for our inquiry.

Postulates.

First Belief.—That my present thoughts exist.

Second Belief.—That my remembered thoughts have existed.

These two beliefs involve a third, viz.:

Third Belief.—That time relations exist.

Fourth Belief.—That minds more or less resembling mine exist in my fellow-men and in some other animals.

Observation.—By intercourse between my mind and the minds of my fellow-men I learn that they experience sensations which are closely related to those that present themselves as a part of my mind. Whence, and from much other evidence, I infer:

Fifth Belief.—That my sensations and theirs have their source in some existing thing or things which are not any part of my own present or past thoughts.

Bishop Berkeley entertained this belief as emphatically as other men. He held that sensations are produced in human minds by acts of will of a "governing spirit."

Sixth Supposition.—Another belief is freely made use of in the present essay, viz.: that my organs of sense and parts of my brain are in some way associated with the introduction of sensations into my group of thoughts.

This belief is, however, not a necessary postulate of the investigation. The argument can be stated in language which does not

include it; but the supposition is true, and therefore unobjectionable, and it is introduced thus early because without it we should be obliged to use unfamiliar forms of expression which would be less perspicuous.

With the same end in view, viz., to attain lucidity, the language of causation is freely used throughout the essay, but will be found not to involve anything beyond what is included in the fifth of our postulates until we enter on the consideration of "efficient" causes.

Chapter 7. Of Egoistic Auta, and of Sense-compelling Auta.

My own thoughts are, at all events, things that exist (Postulates 1 and 2): they at least are auta so long as they last. They are, accordingly, while they last, a part of the universe of existing things. But they are not the whole of that universe. In the first place, the thoughts of other men and the thoughts of the lower animals are also things that exist (Postulate 4). And beside all these auta there are also auta of the kind that produce effects within men's minds through their [organs of sense][1] (Postulate 5). This is a complete enumeration of auta—things that exist—so far as known to man.

The minds of my fellow-men and the minds of the lower animals may conveniently be classed along with my mind as *the egoistic part* of the universe—being the part of the universe which I am already in a position to know consists of auta of the same kind as those that make up the ego.

Auta of the other kind we may provisionally speak of as *sense-compelling auta*, in contradistinction to my mind and the minds of other men and animals, which are groups of auta that receive certain definite additions when and so long as our [organs of sense] are forced into action by sense-compelling auta. The totality of these sense-compelling auta we may, for brevity, designate *the*

[1] By [organs of sense], within square brackets, are to be understood the real existences, the antitheta in the autic universe, which cause in us those perceptions which when synthetized furnish the phenomenal objects to which the term *organs of sense* is also applicable, and which, when we have occasion to distinguish them from their antitheta, may be written [organs of sense]′, with a dash.

The antitheta are popularly imagined to be 'material substances' of the phenomenal objects: but this conception of them conveys an entirely erroneous idea, as will appear in the sequel. See also Chapter 4, above.

sense-compelling universe, which will accordingly mean the same as the sense-compelling part of the universe.

The whole universe, then, as known to man, consists of this sense-compelling universe and of the thoughts of men and animals. This division is convenient, although it is faulty from a logical point of view, since we shall find that the parts of which it consists overlap. We shall, nevertheless, make use of the distinction provisionally, for the sake of its great convenience to us, *i.e.*, to minds that consist of egoistic auta when venturing upon the study of other autic existences.

Chapter 8. Of the Communications Made to Me by the Sense-compelling Part of the Universe.

Now when I open my eyes or exercise any of my other senses, sense-compelling auta transmit messages to me through my [organs of sense]. These messages finally present themselves as parts of my mind, of *my* group of thoughts; and *in the actual form in which they arise within my mind* I propose to call them *tekmeria*[1]—signs within my mind that events are happening in a part of the universe that is distinct from my mind. Thus, when I look towards the fire in the room in which I sit, the actual existence, the sense-compelling auto, the antitheton of the phenomenal object, which in its relation to us it is appropriate to call the aitio-fire (*το αἴτιον*, that *part* of the entire body of causes leading up to anything to which we may *attribute* that thing), transmits one message or signal to me through my [eyes], viz.: what is commonly called the visual appearance of the fire. This is one tekmerion made to be a part of my mind by the aitio-fire so long as it is acting upon me. When, at the same time, I hold out my hands, it transmits a second message to me, the perception of warmth, through another of [my senses]. And it sends another tekmerion to me, another witness that it is in existence and producing effects, through my [sense of hearing], viz.: the sound of the flame playing over the coals.

Thus, so long as I am employing my senses upon the fire, some cause which is distinct from my mind, *i.e.*, which is not a part of my little group of thoughts, is in three different ways and in each of them a very indirect way, sending me what may be called telegraphic signals; and these three tekmeria become, for the time, a part of that fluctuating group of thoughts which is my mind.

[1] *Τεκμήριον*, a sign which is at the same time a proof of something.

To prevent misapprehension, it may be well, before going farther, to invite attention to the guarded statements that have been made, which, while embodying the whole of what may, up to the present, be legitimately inferred from the six postulates upon which we construct our argument, do not include the further illegitimate statement, which is usually added, that the aition, or source from which the messages have been transmitted to our mind, is a 'material substance' occupying that portion of space which is apparently occupied by the phenomenal object. This mistake, so often made, seems to have its source in an impression that the cause (the aition) will resemble its effects (the perceptions which, when synthetized, build up the phenomenal object). The presumption is quite the other way; notwithstanding which, when men are forming their ontological judgments (and all men have to form ontological judgments of one kind or another), they often tacitly assume that causes are like their effects, or suppose that the relations between the causes are of the same kind as those which they find prevailing among the effects. We should be very carefully on our guard against these errors.

What may legitimately be stated is that some of the auta of the sense-compelling universe have been operating upon one another, and have produced extensive changes—changes which may have affected the auta themselves or their relations and operations. Of this widespread effect, some small—excessively small—outlying portions have filtered as far as to my mind, to my little group of auta, through a chain of intermediate effects within certain narrow and tortuous channels, my [organs of sense]. In the form in which they ultimately reach me they are *tekmeria*, signs to me that events are occurring beyond my own mind.

Chapter 9. Of My Mind and Its Synergos.

In ontology we are confronted with a difficulty bearing some relation to that experienced by biologists in their attempts to arrange the genera and species of plants or animals in a satisfactory natural order. In their floras and faunas they are obliged to adopt a linear arrangement; whereas the progress of the events that brought about the morphology with which they are dealing did not follow any such single line. So, in ontology, expositions, like that here attempted, must proceed, chapter after chapter, in a linear pro-

gression; whereas at one stage we may find ourselves in want of knowledge that cannot be satisfactorily dealt with till some subsequent stage. We are in this predicament at present. For further progress in this inquiry it is essential that we shall know something about the synergos (*συνεργός*, a coadjutor or co-operator) which is associated with my mind in all, or almost all, its operations, which contributes largely to every message that my mind receives from abroad, and to every message that comes down to it through memory from its own earlier experiences; and without which my mind would, in fact, be an absolute blank as regards all that is going on outside itself, and would be destitute of any knowledge of its own past thoughts. As the relations between this synergos and the mind have to be dealt with prematurely, the reader is requested to pardon the intrusion into this chapter of matter which cannot be adequately expounded till farther on.

The [events]′ in a man's brain[1] which are associated with the thoughts that are his mind, do not occur except while the man is alive; and only, during life, when he is either awake or dreaming. All these objective events can be shown to resolve themselves in ultimate analysis into motions of one kind or another going on in, or in connection with, the brain. But they are far from being the whole of the motions of which (under the diacrinominal view of nature, see Chapter 17) the brain consists—in fact, they are an excessively small and quite peculiar selection from the totality of motions that are the brain. It is possible to satisfy ourselves of this by instituting a comparison of time relations. Accordingly, a bystander would see this selection of motions going on in my brain while I am awake, if he could make it an object of observation, and if his senses were acute enough to see all that is going on objectively. If, however, he could see all that is going on objectively, he would see a vast deal more than the changes or motions that are associated with my thoughts. We thus, and from other evidence, learn that the aitio-brain—the source in the autic universe of the perceptions and ultra-perceptions which make up that object of nature which we call the brain—is a collection of auta which includes many more auta besides those that are my mind: and these 'many more auta' are the synergos.

[1] By [events]′ is to be understood events in the *objective* world which we call nature. If written [events], without the dash, it would denote events in the universe of auta.

The group of auta which includes the auta that make up the mind along with those that make up its synergos, is the true existence in the autic universe which corresponds to that natural object which we call the brain. The prevalent belief that the true existence is a 'material substance' hovering about that portion of space within which the phenomenal object appears to be situated, is an utter mistake, although it is a belief which has been handed down to us by generations of our predecessors, and in which we were all brought up. Numberless are the errors which have crystallized about the phrase 'material substance'; and the mischief that has been wrought by them may be judged from the circumstance that they have quite shut out of view the wonderful capabilities of the true autic existences, of which we get one very instructive glimpse when we find that the thoughts that are our mind are a small—a very small—part of one of them.

Superstance would be a less misleading term than substance; but it is better to cut ourselves completely adrift from all the misleading associations bound up with the word substance. When the relation between a natural object and its autic cause is under consideration, the present writer has found it convenient to speak of the natural object as the *protheton* and the autic cause in the sense-compelling universe as its *antitheton*. Using this nomenclature, the *brain* of a man is a protheton, and his *mind* + *synergos* are its antitheton. The mind + synergos are a part of the true autic universe: the brain is a part of that hypotheton which we call nature.[1]

With this imperfect treatment of the subject we must be content

[1] The labors of physiologists lead to the conclusion that no thought becomes a part of the mind of any animal without being accompanied by some change in its brain, using the word brain here to mean, not the onto-brain but the objective brain, which is a part of nature. These objective changes are motions of some kind Hence we find here an instance in which the autic anthitheta of certain motions *are thoughts*.

The above relation is often so stated as to imply that the change in the brain is in some way the cause of the thought. This is to mistake the weather-cock for the wind. What occurs in the autic universe is the cause of the appearance of change in nature, and not *vice versâ*.

Nevertheless it is legitimate for physiologists to work, as they usually do, under the *hypothesis* that it is the objective events that cause the autic; provided that they do not make the mistake of supposing that this interchange between cause and effect is theory.

until we can resume the discussion with the advantage of having learned what a natural object is, and what space relations are.

Chapter 10. Of Perceptions.

The tekmeria, the messages from abroad, as I experience them when an auto acts on me through my [senses], are more than mere sensations. To enable me to see this it is only necessary for me to direct my attention to the remarkable judgments about space relations which have annexed themselves to, and in some cases even substituted themselves for, my sensations. When I hurt my foot and when I hurt my elbow there is a difference in the sensations; and this difference my mind, largely assisted by the synergos,[1] has come to translate into *the perception of a space relation* between these two sensations, and between them and others. Thus the first pain is felt as a pain in the foot, *i.e.*, *in or about a certain position in space;* the second pain I similarly *localize*. So also with other sensations when they have come to be transformed into perceptions. The red which I now see in each coal of the fire is a sensation which seems to me of a certain shape and size, and at a certain distance from muscular sensations which I feel at the same time, viz.: the sensation of turning my head towards the fire, of converging my eyes in succession upon different parts of it, the sensation of now and then winking, and the sensation of making and maintaining the focal adjustment of my eyes: all of which latter

[1] The physiological view of these events would be somewhat as follows: the hurt foot and the hurt elbow are in communication with different regions of the brain, and the [effects]′ produced in the brain are not the same in the two cases. Although part of these effects are the protheton of the thought in the mind, much more of them are the protheton of changes in the synergos; for, whatever the change in the brain has been, it *must* have included a body of molecular events and others with time-relations too rapidly varying to be the protheton of any such slowly changing auto as a human thought. These accordingly are part of the protheton of the synergos, since the brain as a whole is the protheton of that group of auta which includes both the thoughts that are the mind and those other auta that are the synergos. And as the more slowly changing events in the brain and those that change more rapidly are so interdependent that neither can be other than it is, without its affecting the other, so are the thoughts in the mind and the autic events in the synergos interwoven and they affect each other. It would also appear that in dreamless sleep, those special slower events spoken of above cease to occur within the brain. But some, at least, of the swifter ones are still present, so that at such times the whole antitheton of the objective brain consists of the synergos only.

sensations appear to me to be located elsewhere, viz.: at or near *the centre of space*, as *I* apprehend space. So also with the sensation of warmth which seems to me to be *on the surface of my hands* when I hold them to the fire. Now sensations which thus appear to occupy positions in space are *perceptions*.[1]

In such cases the perception is far from being a mere coexistence of sensations. It is the result of a very subtle synthesis, a synthesis usually of many sensations and of my mind's present and past experience, with probably other materials. My mind assisted by its synergos could not have effected this synthesis but for their inherited tendency to make it and their inherited capacity for doing so.

By the synthesis which results in my *visual* perceptions, a very remarkable co-ordination has been effected between the muscular, the tactual and the visual sensations produced in me by sense-compelling auta; an equally remarkable co-ordination between the perceptions of my own mind and the perceptions of my fellow-men and of other animals; above all a co-ordination between my own perceptions, past, present and future: which co-ordinations enable me promptly to form correct predictions and are *of the greatest service to me in regulating my acts*. Natural selection has probably helped to develop them. Of all the syntheses by which the mind assisted by its synergos succeeds in translating sensations into perceptions, that which provides us with our visual perceptions appear to accomplish the greatest and most useful transformation. The intense tendency to make this particular synthesis and the extraordinary facility with which I can effect it, are no doubt due to the frequent repetition of the process in an immense series of progenitors: and, in fact, there is evidence to show that the co-ordination, substantially as my synergos and I now make it, had been effected in my ancestors at a very remote geological period.[2]

[1] Perceptions are distinguished from our other thoughts by having relation to *two* situations in space—to that position in space which the object observed seems to occupy (or, in the case of warmth, to some situation on the surface of the body), and to that position which seems to be occupied by the portion of the brain which is affected when this particular thought presents itself in the mind. Our *other* thoughts—affections, beliefs, sentiments, motives, etc.—have relation to only one of these situations in space, viz.: to the situation in which the part of the brain affected seems to be located.

[2] Before birds were differentiated from other vertebrates. See the marvelous representation of balls within sockets or beans within a pod, each supported by a little stalk, which is found on the secondary wing feathers of the male Argus

A synthesis does not mean merely the act of collecting materials together. It means that and much more, viz.: the building up of a definite structure (*συντίθημι* includes the meaning of the Latin verb *construere* as well as of *colligere*). The completed structure may be conveniently called the *syntheton* (*σύνθετον*, the structure resulting from synthesis).

It is to be noted that these syntheta, my perceptions, while they last are auta, real existences: they are thoughts, parts of my mind. In fact, up to the present we have been dealing exclusively with auta, things that really exist, some of them non-egoistic, others of them parts of my own little group of auta. But in the next step which the mind takes—a very important step—it transcends these limits.

Chapter II. Of Hypotheta.

Hitherto we have treated of auta, *i.e.*, real existences, with as little reference to hypotheta, or supposed existences, as was found practicable. It is impossible for a student of ontology commencing his inquiry from the mental attitude in which we, men, must start, wholly to disentangle auta and hypotheta from one another in the earlier stages of his inquiry; but this becomes more and more feasible as he proceeds, until, in the end, there need be no outstanding confusion at all.

In the present chapter we direct our attention to what is probably the most important hypothesis that the human mind makes, a hypothesis of which we all make daily use, and which confers upon me and upon my fellow-men and upon other animals—in fact, upon

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pheasant. This most astonishing work of art produced, by nature, is effected by six or seven different colors or shades of color disposed in the same way in which a human artist would lay them on with his brush to produce the same effect.

Darwin, in his *Descent of Man*, has shown how Variation with the coöperation of Thoughts in the minds of the cock and hen pheasants, can account for the development of these wonderful artistic productions. The thought on the part of the cock is a desire or impulse to please the hen by an exhibition of his plumage, and the thought on the part of the hen is an appreciation of different degrees of excellence in the artistic effect achieved in the pictures submitted to her judgment. This implies that the hen bird possesses the same wonderful power that we possess of translating coloring and shading into form; which therefore was attained by our ancestors before birds were differentiated from other vertebrates, unless (which is less probable) it has been separately developed along the two lines of descent since that time.

all the minds that consist of egoistic auta, *i.e.*, minds which are supplied with information through organs of sense—an inestimable benefit, by creating for our advantage those *supposed* existences which are called natural objects. They arise in the way described in the next paragraph: and according as we make progress in tracing out the way in which they arise, it will become obvious why they do us such inestimable service.

Perceptions—*i.e.*, sensations which appear to me to be planted out in space—are the tekmeria or messages which I receive from sense-compelling auta. Auta of this kind form a part of my group of thoughts whenever and so long as any sense-compelling auto is acting on my mind and my synergos, through my senses. But the perceptions which it creates within me at any one time are but a small part of all the tekmeria that it can send to me. Which of all the possible tekmeria shall exist at any one instant depends on the particular line of communication which is at that time open between the sense-compelling auto and me; and whenever I make those changes which are popularly described as "looking at the object from a different side," "touching it in a different place," and so on, what I do is simply to change the channel of communication without altering the sense-compelling auto. But I thereby alter the perceptions, the tekmeria which reach me from it. Now the sensible *object*—which persons untrained in the study of their own mind are apt to mistake for the cause of their sensations—is simply the result of the mind and its synergos effecting a synthesis of all these tekmeria. They cannot actually exist, except in succession; but my mind, aided by its synergos, has the power of *conceiving* them as though they existed—

1. Simultaneously,
2. Persistently, and
3. Without being any part of itself.

In this power of conception consists its power of effecting this most useful synthesis.

It is of importance to bear in mind that while I am what is called "looking at the object," one of the tekmeria, my visual perception at that time is *actual*—that is, it is in true autic existence; the rest of the perceptions which are compacted along with it to make up the syntheton are *potential*—that is, they are not at present in existence, but they can be brought into existence. When I "turn

my eyes away," none of the tekmeria are actual: they are all potential. Meanwhile the originating auto continues in existence during all this performance, and will, with certainty, reproduce the first-mentioned tekmerion if "I turn my eyes back," *i.e.*, if the channel of communication between the sense-compelling auto and me is reopened.

It thus appears that the sensible *object* is not at all made up of any of the parts of which the sense-compelling *auto* consists, but only of certain minute outlying portions of the widespread effects of its great activity, viz.: those effects which, by its activity, it can produce within me through a few narrow and tortuous passages; while at the same time most of its great activity is being expended in other directions. This clearly shows—

1. That the sensible object is not the auto; and
2. That for all human purposes my attaining a knowledge of this hypothetical existence is as useful to me as if I knew what the auto is.

It, in fact, tells me, *in a direct and in the most compendious form*, what effects the auto, under every variety of circumstances, *will produce within me;* for it is itself a structure *built up of these very effects put together.*

It is to be observed that ordinary language is throughout built upon the erroneous popular belief that the objects of the phenomenal world are existences, in the autic sense of that term; and, moreover, that they are the cause of the perceptions that come into existence when we exercise our senses. This is a mistake of the kind which is called "putting the car before the horse": it is to imagine that a structure built up out of the effects of a thing can be the cause of those effects. The sensible object is built up of perceptions instead of being the cause of them. Their cause is to be sought in the sense-compelling universe of *auta*, not in the phenomenal world of *objects*. We must always be careful to distinguish between autic or true existence and objective existence, which means forming a part of that great objective hypotheton which we call nature. We may sometimes find it convenient to distinguish between them by writing [existence] for autic existence, and [existence]′ for objective existence. Autic existence means existence in the absolute meaning of that term; objective existence

means existence in a relative sense, namely, what we are to regard as existence under the Objective Hypothesis.

Ordinary language suggests to all who use it a number of mistakes of the kind referred to in the last paragraph. It is, accordingly, apt to mislead us very much, and we must be constantly on our guard against illusions into which we may but too easily be led by the usages of common speech, and by associations which have grown up around familiar forms of expression. Illusions will be found to lurk in what are apparently quite harmless forms of expression, such as "I perceive a cloud moving across the sky"; and to get at what we are really justified in believing, it is well *diligently to practice ourselves* in converting such expressions into less misleading forms, *until we do so with facility*. Thus the foregoing statement is equivalent to—

1. I am a fluctuating group of associated thoughts, and the perception of a moving cloud is for a short time one of this group. This is an autic group.
2. The perception of a moving cloud is also a part of *another* group, in which it is joined, not with the other thoughts at present in my mind, but with all the other perceptions which the antitheton of the cloud *could successively produce* in my mind.
3. This useful hypothetical group, which may be called the objective cloud, is not the cause of my perceptions. Their true cause must be sought elsewhere, and, to give it a name, it may be called the aitio-cloud, or the onto-cloud. It is the antitheton, in the autic universe, of the objective cloud. The objective cloud is the protheton of this real existence, and is a part of the great hypotheton which we call nature.

Nature is here used to signify the totality of all *sensible objects*. This definition is in accordance with the usual acceptation of that term.

We have passed successively under review two acts of synthesis —the *synthesis of the first order*, whereby sensations are transformed into perceptions; and the further synthesis, which may be called a *synthesis of the second order*, whereby perceptions are built together into the sensible objects around us, each of which is a kind of synopton, or collected view, of materials only a small part of which

are in existence at any one time. But, in reality, these two acts of synthesis are now carried on by my mind and its synergos simultaneously and with astonishing ease and promptitude; and it is probable that the gradually acquired power to make them was developed *pari passu* in my ancestors at a very remote geological period.

The instinct which impels us to assign a position in space to sensations affects our visual and tactual sensations most, including under the latter term our muscular sensations, as well as sensations of roughness, smoothness, resistance, hardness, softness, and some others. We also perceive it conspicuously in the allied sensations of tickling, warmth, coolness, pain, and several others. We localize with somewhat less precision our sensations of taste and smell: and of all our more conspicuous sensations sound is that which we least refer to a definite position. We have less power of doing so than many other animals who are furnished with ears which can be turned so as to distinguish the direction of sound; and far less power than some nocturnal insects who, by their feathery antennæ, which are their auditory apparatus, are able to determine the direction of a sound with a precision approaching that of eyesight.[1] In man there are but slender materials for the synthesis.

It may make some parts of this and of the succeeding chapters clearer to give here a definition of the term *object*. This term might be applied to the objects of any hypothesis, *i.e.*, to the *supposed* existing things, which we are to suppose to be in existence so long as we are making use of the hypothesis. Thus, under the hypothesis made use of in Geometrical Optics, it would be intelligible to speak of rays in front of a mirror as having an *objective* existence; which would mean that they are the 'objects' of that hypothesis, viz.: what we are to regard as being in existence under that hypothesis. But it is usual to make the terms object and objective more definite by restricting them to one particular hypothesis; and unless it is otherwise specified, they will be applied in the present essay only to the objects of that *great* objective hypothesis described in the present chapter, which by 'the synthesis of the second order' supplies us with what are popularly called the natural objects about us.

[1] See Professor Alfred M. Mayer's experiments on the mosquito, in which he satisfied himself that the male insect can determine the direction of a sound within an angle of 5° (*Philosophical Magazine* for November, 1874, p. 380).

Men and dogs and other animals, and among men different individuals, are able to make this synthesis with more or less success. It is made with most success when the *conceived* perceptions, which are so large a part of the syntheton, are correct pictures in the mind of what they would prove to be if the proper measures were taken to make them in succession actual perceptions. Accordingly, the 'objects of nature' about us may appear to one man somewhat different to what they do to another. In the present chapter we have dealt with them as 'sensible objects,' *i.e.*, as the objects of nature, such as they present themselves to 'the man in the street.' In subsequent chapters we shall deal with them as they present themselves to scientific men; and it will then become apparent why the scientific objects of nature are to be regarded as constructed with more success than the mere sensible objects of uninstructed men.

It may also be noted that, while we are what is popularly described as 'looking at' or 'touching' or in other ways 'exercising our senses upon' the objects about us, these syntheta of perceptions are made up of perceptions a very small part of which are in autic existence, while the bulk of them have only an objective, *i.e.*, a supposed, existence. Thus, while I am looking at a chair or table, the sensible object is made up of my actual visual perception at that time, and of a great body of conceived perceptions which have to be joined to it to make up the whole syntheton: there is, as it were, a veneer of auto with a hinterland of hypotheta; forming, when combined, a syntheton which, viewed as a whole, is a hypotheton.

Chapter 12. Of the Physical Hypothesis.

It will be well to treat of the Physical Hypothesis next, as it is a hypothesis which is entertained and made use of, with more or less success, by all men, and not by scientific men only.

Natural science may be defined as the investigation of how nature [works]', of how and why events in nature [occur]'. In this definition we have to use the verbs *work* and *occur* in their objective sense, since what have [really] done the work have been, not the hypotheta which people the objective world, but their antitheta in the universe of real existences. The relation between what goes on in the autic universe and the events which as a consequence appear in the objective world may be likened to the relation between the

motions of a great machine and the movements amongst the shadows which the parts of the machine cast when the sun shines. If the machine moves in an orderly manner, so also will the shadows move in an orderly manner; and Natural Science is the study of these movements amongst the shadows. If we had adequate access to the machine, the best way to investigate the movements of the shadows would be to study what takes place in the machine, and from it to forecast what must happen among the shadows. But, unfortunately, though we can see the shadows, we can bring only an excessively small part of the machine under close inspection, and we have but glimpses of the rest. The only part of the stupendous autic universe which a human being can *adequately* examine is that excessively small group of auta which are the thoughts of his own mind, with the similarly small groups that are the minds of his fellowmen and of some other animals: he cannot even make any adequate study of the events that go on within the synergos which is so closely associated with his mind, and can only collect mere scraps of information as to what the real events are throughout the rest of the vast machine. As to that tiny group of auta that are one human being's thoughts, it bears somewhat the same relation to the mighty whole of the autic universe as their protheton, namely, some of the more slowly changing events within the cortex of his brain, bears to the enormous totality of motions that are going on objectively throughout the whole of nature. This makes it evident that the part of the autic universe that man can adequately examine is but one drop of an immeasurable ocean, and although that little drop is an actual specimen of the kind of things that auta are, it is very plain that we are not justified in assuming that it is a fair *average* specimen of them.

Working under these disadvantages, man (and the same is true of the more intelligent of the lower animals) has constructed the *Physical Hypothesis* whereby to enable him to form a correct forecast of the changes which will occur in nature. The physical hypothesis is the supposition *that the objects of nature can act on one another*, either directly (action at a distance) or through intervening media (which by many is supposed to be an essentially different kind of action). Now the objects of nature are syntheta of perceptions and ultraperceptions (as appears from the last chapter read along with those which follow); and syntheta of perceptions cannot be what really act. Nevertheless, it is eminently useful to carry on our investiga-

tion under the physical hypothesis that it is they which act, and to confine our efforts to tracing out what effects this action must be supposed capable of producing, and under what laws it must operate, in order that it may account for what occurs in nature.

This, however, is felt by many persons to be too abstract an attitude of mind; and, to satisfy them, and import into the hypothesis the plausibility which they demand, by relieving the fundamental conceptions of what is oppressively felt as the absurdity of supposing that syntheta of perceptions act, it is usual to supplement the syntheta by piling an aërial Pelion upon this solid Ossa, and by supposing that in addition to the *sensible object* which occupies any portion of space there is what is called *its material substance* occupying the same position, which, partly directly and partly by its motions, acts on other material substances—the ether being one of these so-called *substances*. According to this, which is the prevalent hypothesis among both scientific and non-scientific men, it is these 'substances' which travel about through space; and the sensible objects, which are what we see and feel, are supposed to accompany them in their peregrinations by reason of the way in which they, the substances, act (usually through intermediate 'substances') upon our organs of sense.

This is the usual point of view: but more careful thinkers will do well to eschew this somewhat convenient, but by no means necessary, encumbrance upon *the unadulterated process of physical investigation* which treats the sensible objects themselves, the bare syntheta of perceptions and ultra-perceptions, as though they were what bring about the changes that occur in nature; and will do well to occupy themselves exclusively in tracing out the laws that must, under this *hypothesis*, be in operation in order that the effects may be what they are.

This, the true physical hypothesis, is eminently useful and is therefore legitimate; but the addition that has been saddled upon it, that there are 'material substances' present, is unnecessary, and as it is misleading and tends to keep out of view the really existent autic universe, it ought to be discarded by all persons who wish to think clearly. This is the course which all careful thinkers should prefer, because it keeps clearly before our minds that in the Physical Hypothesis we make use of a hypothesis and not of a theory. By being thus careful we avoid the risk of throwing dust in our own eyes. It cannot be too distinctly kept in view that the

justification of the physical hypothesis is its utility, not its truth—its incomparable efficiency as a means of investigating nature. This is a matter about which it is far better, although it cannot be said to be essential, that students of Physics should make no mistake.

It is obvious that causation, in the full sense of that term, can operate only between the real existences of the autic universe, and that everything else that appears to us to take place is a consequence of what occurs there. In fact, efficient cause and autic cause are synonymous terms.

Nevertheless, it is convenient and quite legitimate for scientific men to speak of 'physical' causes, meaning thereby what they have to treat as causes when engaged in carrying on an investigation under the Physical Hypothesis.

A very useful scaffolding which helps us in building up our investigation is the introduction of *forces* between the physical cause (which is always the vicinity of some natural object) and the effect to be attributed to it under the physical hypothesis. We are thus enabled to speak of the acceleration of a stone in its fall towards the earth, either as being due to the neighborhood of the earth, or as being caused by a force of gravitation which acts on it, which force is, in its turn, regarded as brought into existence by the proximity of the earth to the stone. The introduction of this piece of intermediate scaffolding is found to be of service—

1. Because the force can be represented by a line whose length accurately represents the intensity, and whose direction accurately represents the direction, *of the effect upon the stone* of the vicinity of the earth;
2. Because the same effect upon the stone might have been due to other physical causes, as, for example, to a spring urging it forwards; in which case the same piece of scaffolding, a force represented by the same line in the same position, would occupy its place between the cause and the effect; and
3. Because the effect might have been different, while the physical cause remained the same: thus, if the stone lay on the ground, what the vicinity of the earth would have occasioned is stress between the stone and the ground.

Accordingly, by referring effects in nature to the operation of

forces, we are enabled in each case to indicate with accuracy *the intensity and direction of the effect*, without having to specify (*a*) which of several possible physical causes is the one in operation, or (*b*) which of the possible kinds of effect is that which is being produced: and this in practice is found to be an immense convenience.

Such is an outline of the principles that underlie the dynamical investigation of nature, which is the form of investigation that penetrates most deeply into its secrets.

Chapter 13. Of Space Relations.

In order to apprehend clearly how much has been accomplished by synthesis it is advisable that we should scrutinize more closely space relations, and man's instinctive judgments about them: and as these judgments are a more conspicuous factor of my visual and tactual perceptions than of others, it will be instructive to treat specially of them.

Many slight muscular and other feeble sensations accompany the use of my visual and tactual organs of sense. These obscure sensations are constantly changing while I am using those senses, and in an excessively complicated way. That out of such tangled material synthesis has been able to evolve so simple a result as my judgment about space relations is because, amid all the apparent disorder, there *do exist* [*real*] *relations* between those much varying sensations; and the syntheton which can be produced depends on what these relations are. They in turn depend on what relations exist between my [organs of sense] and the various parts of the auto which is transmitting messages to me; for it is while varying these that the sensations in question arise. Hence, finally, the synthesis which can be effected *depends on what relations prevail in the autic universe between my* [*organs of sense*] *and other parts of that universe.* We have no reason to suppose that these onto-relations as they may be called, these relations between auta, are in the least *like* space relations, the space relations being syntheta constructed out of the obscure sensations that are indirectly occasioned by the onto-relations, after these have been worked up by the mind and its synergos with memories of past experiences and other materials.

Whatever the onto-relations may actually be, *they are at all events*

a part of those conditions in the autic universe which determine whether auta can act upon auta. So much I know, because I have to adapt my organs of sense to them in order to get tekmeria; and it is in doing this that I experience the complicated sensations which have come, by reason of what has occurred in my long series of ancestors, to be synthetized for me into instinctive judgments of objective space relations between perceptions. It is evident then that my judgments about space relations are the result of a synthesis of materials which are themselves consequences of relations that prevail in the autic sense-compelling universe. It is these onto-relations, whatever they are, that have an autic [existence]: the space relations have only an objective [existence]'. This means that we are to treat these space relations *as though they existed* whenever we are availing ourselves of the great and most useful objective *hypothesis*, which supposes that not only do our perceptions exist but that the hinterland also exists which with them make up what are called the natural objects about us. But while making every possible use of this hypothesis, we ought, if we care to think clearly, to keep steadily before our minds that this is a hypothesis *to be made use of*, but not the correct theory *to be believed.*

Chapter 14. Of Motion.

We are now in a position to deal with the important subject of motion. The *appearance* of motion is an auto, a perception in my mind; and while this perception lasts it is a tekmerion, a proof to me that an event capable of producing this appearance has occurred in the sense-compelling autic universe. This event could send different tekmeria to me, according to the way I employ my senses upon it; and the syntheton formed by putting all these together is what is meant by the term *motion.* It is accordingly a part of the great objective Hypotheton which we call Nature. If we want to indicate the real occurrence in the sense-compelling universe, we may speak of it as the onto-motion or aitio-motion, meaning by these terms the autic event which corresponds to the synthetomotion in the objective world. It is an antitheton, and the synthetomotion is the corresponding protheton. The word motion, like all similar terms, is ambiguous, and in common speech it has to be sometimes interpreted as meaning the protheton in the objective world, and in other contexts as meaning its antitheton in the uni-

verse of real existences. The protheton is in fact a kind of synopton, or conjoint view, of the actual effects which are at that time being produced and of the possible effects that might have been produced, within modern men's minds, by its antitheton the ontomotion. It is necessary to describe it as a *kind of* synopton, since the materials that come in, or could come in, from abroad are modified by being worked up with materials contributed by the mind and its synergos.

Chapter 15. Of the Phenomenon, or Phenomenal Thought; and of its Relation to the Phenomenal Object.

The word phenomenon has three established meanings: 1. It is used by metaphysicians to mean thought in the mind. This is the original or at least an early meaning of the term: the other meanings are of recent date. 2. It is used to mean an extraordinary circumstance. This is the popular acceptation of the word. 3. It is used to mean any natural object or event in nature. This is the meaning attributed to it in works on Natural Science.

For the sake of convenience it is well to assign a name to my thought about an object of nature, or as it is often called a phenomenal or sensible object. My thought about it we may call the phenomenon, or phenomenal thought, availing ourselves of the first of the above meanings of this term. Accordingly the phenomenon within my mind at any particular time consists of all or some of the following:

1. The actual perceptions which at that time the sense-compelling auto is producing in me, if there are any such perceptions existing in my mind at that time.
2. My memory of the perceptions which that auto has on other occasions produced in me.
3. My anticipation of such perceptions as I suppose it would produce in me under other circumstances.
4. Certain suppositions with respect to this group of perceptions.

This phenomenon, or phenomenal thought, is itself an auto, a part of my group of thoughts; while, in contrast to this, it is only as a hypothesis that *the object of this thought*, the phenomenal object, can as a whole be regarded as in existence. Part of it no doubt

may be temporarily in existence, viz.: so long as the sense-compelling auto which is the source of the perceptions happens to be acting on me through my senses. During this time some of the perceptions that go to make up the phenomenal object *are in actual existence*, but only as a part of my group of thoughts. None are in existence independently of the mind, nor are any of the rest of the perceptions that go to make up the phenomenal object in existence at that time either in or out of the mind. That the whole phenomenal object is supposed to be in existence and to be distinct from the mind is therefore *a hypothesis;* most useful, but not to be thought of as *the true theory*. On the other hand, the *phenomenon, i.e.*, my thought about the phenomenal object, while it has the advantage of being an auto, is transitory, imperfect, very variable, and almost always erroneous in some respects; depending as it does on the extent of my information and the amount of attention I give to it: while the *phenomenal object*, though a hypotheton, has in it nothing in the least shifting or arbitrary. *It is perfectly definite:* including as it must *all the tekmeria* which its antitheton, the sense-compelling auto, *does* actually *or can legitimately* create in human minds through human organs of sense. It is intended by the word *legitimately* to exclude cases of illusion, or defects that arise through imperfection of the senses. Legitimately is to be understood as meaning when every part of the line of communication is working normally and satisfactorily.

Chapter 16. Of the Phenomenal Object, with which Natural Science Deals.

It is in accordance with the signification we have given to the word [real]′, when written with a dash, that motion in the phenomenal world shall be deemed real when it is a syntheton of the actual perceptions which an onto-motion does or of the potential perceptions which it could produce by acting on human minds through human senses. But Science, in its progress, has found this definition too cramped. The definition would limit the stamp of being *real* to those cases in which man's senses are competent to act as channels of communication between the sense-compelling universe and him. Now, scientific investigation has penetrated much farther than this—even the flimsy appreciation of what goes on in nature which is necessary for man's everyday work, renders

essential some extension of the meaning of the word *real*—and accordingly the exigencies of common life, but more especially of scientific inquiry, have made an extension inevitable, so that a motion or other part of the Objective Hypotheton is still to be regarded as [real]′, although too small or too rapid or in some other way unfitted by its time or space relations to be a syntheton of human perceptions, *whenever justification for this extension exists*. The objects with which the scientific student of Nature has to deal are in fact syntheta of—

1. Actual perceptions;
2. Potential perceptions; and of
3. Certain ultra perceptions, namely, those which scientific investigation does or can warrant.

By an ultra perception is to be understood what would be a perception, if our senses were more acute.

These are more than the syntheta of actual and potential human perceptions which we have called sensible objects, and to distinguish them it will be well to give them a different name. We shall call them *phenomenal objects*. They are in much closer relation to what is actually going forward in the autic universe than it is possible for the 'sensible objects' to be. This is a necessary consequence of the restricted range of the senses possessed by man, by which the amount of detail which can be present in the sensible object is limited.

Chapter 17. Of the Diacrinominal Object.

Motions are by far the most important part of the phenomenal hypotheton, as will be obvious from the following considerations. Scientific investigation has brought to light the significant facts which are described in common language by saying that men and animals receive their sensations of sound from motion in the air, of light from events in the ether which can be ultimately analyzed into motions, and in the same way their other sensations from motions somewhere in Nature. This, put into less objectionable language, is equivalent to the statement that the auta and autic events of the sense-compelling universe which produce in me the sensation of sound through one channel of communication, viz., through my sense of hearing, are such as are also competent to produce in me through other channels, namely, through my senses of sight and

touch, another tekmerion, viz.: the perception of motion; or, at least, differ only from those autic causes which are capable of producing an actual perception of motion through those senses, in the way that the autic cause of the perception of one visible motion differs from the autic cause of the perception of a similar visible motion which is swifter or slower or on a different scale.

These remarkable discoveries have led scientific men to entertain a new and very important view of nature, in which it is regarded as made up of objects each of which consists of almost inconceivably minute and swift motions. These and the drifting about in space of some *objects, i.e.*, of some *masses of internal motions*, are the whole of this hypotheton. It may be regarded as the utmost simplification of which any synoptic view of the effects produced within the human mind by the mighty march of actual events in the real universe is susceptible; and it is therefore that synoptic view of those effects which stands in closest relation to the autic causes that have produced them.

The remarkable hypothesis described in the last paragraph may appropriately be called the *Diacrinominal Hypothesis*, as it has discriminated between the various tekmeria produced within us by the autic universe, and has selected for further synthesis one special group—our perceptions of motion—on the ground that it, and that it alone, is able *by itself and without being mixed up with other tekmeria* to people Nature with objects which are *complete* as bodying forth in a collected form the information sent us by the real auta of the actual sense-compelling universe; and which, owing to their simplicity, stand in a closer relation to those auta than the more complex objects of Phenomenal Nature. Phenomenal objects are bright, warm, hard or soft, colored, sweet or bitter, and so on; as well as moving or at rest. In diacrinominal nature motions take the place of all these. An attempt was made to give a summary of the results of this hypothesis in a Friday Evening Discourse, delivered before the Royal Institution of Great Britain in 1885, and printed in the *Journal* of that Society, so that it is the less to be regretted that it would make this paper too long to dilate upon them here. We may therefore pass at once to the consideration of the last circumstance which it seems necessary to make clear in order that we may be at length in a position to understand how the scientific study of objective Nature stands related to the real

existences and real activities of which the true universe actually consists: which is the problem we proposed to investigate.

Chapter 18. Of Physical Causes and of Efficient Causes.

Causation, in the full sense of that term, implying efficiency in the cause, can only prevail in the operations of auta.

When an efficient cause operates within the sense-compelling universe, it produces some change therein, and if this change be such that the sense-compelling universe can produce one set of effects within human minds before the change and another set after the change, then will the hypothetical existence which we call nature also undergo a change. This is because nature before the change is the syntheton made by fitting together the former set of possible effects, and nature after the change is the syntheton of the latter set of possible effects. We may liken the sense-compelling universe to a mighty machine, and nature to a shadow cast by it in a very special way. If the machine is set in motion and changed from one position to another, it produces one shadow before the change and another after; and if the change in the machine has followed a definite order, the second shadow will succeed the first in a corresponding orderly sequence: but the relation between the shadows is not the relation of cause and effect.

Accordingly, in the laws of Nature which have been discovered by scientific investigation we find abundant instances of unfailingly concomitant events and of uniformities of sequence, but not a single instance of genuine cause and effect. The so-called Physical causes are not causes in the full sense of that term. We might write them as [causes]′ with a dash, but not as [causes] without one. Nevertheless it is *legitimate as an hypothesis*, to treat them as though they were causes when and so long as we are engaged in making use of the Objective Hypothesis. If a stone be allowed to drop in the vicinity of the earth, its downward speed is accelerated by a perfectly definite law. In this case the vicinity of the earth to the stone and the acceleration of the stone's vertical velocity are two unfailingly concomitant events. This is one of the Uniformities of Nature which scientific inquiry has brought to light. But *within the domain of Physics* there is no *cause* for the acceleration. To reach the cause we must travel beyond the hypothetical domain of Physics and study the events that have taken place in the universe of real

existences. If we confine our view to Nature, the facts as to what occurs can be observed; the circumstances under which they occur can be investigated; similar cases can be compared; and the laws to which the simultaneous or successive events conform can be brought to light. But here the knowledge conveyed to us by the great Objective Hypothesis ends: Physical Science has said its utmost.

Now all this is changed when we turn to the only field of observation accessible to us in which we are dealing directly with auta. The thoughts of which I consist, the thoughts that are my mind, are auta: no doubt a very small group of auta in the stupendous totality of all auta, but still *an actual sample*, although a very special and perhaps one-sided sample, of what auta are. In the operations that go on in my mind I do find instances, some few instances, of causes producing effects. The familiar case of a geometrical demonstration producing in a man's mind a belief in the truth of the conclusion is a case in point. Here the understanding of the proof is *the efficient cause* of the belief in the conclusion which accompanies that understanding. A wish to accomplish something, and a knowledge of how to go about it, are part of the autic universe since they are thoughts, and they are a part of the efficient cause of subsequent events in the autic universe, unless counteracted by other causes. A few other examples can be obtained from the same small field of investigation: and this is all that man, in his isolated position, has any right to expect; for the bulk of his thoughts are due, at least in large part, to autic causes which lie outside his mind, either in the synergos or beyond it in the sense-compelling part of the universe; and it is there also that those of his thoughts that are known to be causes usually exhibit their effects. When perceptions or when memories arise in my mind, the effect is indeed within my mind, but the cause lies beyond it; and when 'I move my muscles,' the cause is within my mind, but it is outside my mind, upon the antitheta of those muscles, that it operates. The instances are indeed few where the causes and the effects are *both* within my tiny group of auta, and it is only in these few cases that I can have the process of causes producing effects under my inspection.

But since cases can be cited, however few, they suffice *to establish the fact* that the relation of cause and effect in its full sense

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does exist in some instances in the autic universe; whereas it has nowhere any place within the domain of physical science. I am even under the impression that every event which has occurred in the real universe, every change that has taken place there, has been, as a matter of fact, brought about by true adequate causes; although I am bound to admit that man lives too secluded from the rest of the universe, and with channels for communicating with it that are far too indirect, for me to be entitled to dogmatize and to say to myself or my fellow-men that I absolutely know this to be so. At the same time it recommends itself to my mind as intrinsically probable; and it is supported by direct evidence which makes it seem to me *probable* in a high degree—

1. Since there are some instances in which the whole process of causation operating among auta can be observed;
2. Since no instance can be found in which observation is possible, and in which it does not prevail; and
3. Since the alternative supposition appears to be improbable. The only alternative is that, while the few changes among auta which can be investigated are found to be due to adequate causes, the rest, or some of the rest, which we cannot investigate are uncaused.

All men experience within themselves what is called the freedom of their Wills; and this may by some be regarded as presenting an exception to the second of the above statements. But no amount of introspection has enabled me to detect any exercise of my Will which had not been caused by some motive, *i.e.*, by a thought which forms one of my group of thoughts, or else by some inherited or acquired habit; that is, by the intervention of my synergos. This shows me that what I describe as the freedom of my Will does not exclude adequate causes.

It is noteworthy that statistical inquiries have revealed to us the fact that averages taken over great numbers of the acts due to the free exercise of the Wills of human beings, conform to definite laws. This suggests that a corresponding freedom of the Will may prevail throughout the mighty Autos—the totality of all auta—and may, nevertheless, produce perceptions in egoistic minds (*i.e.*, in minds supplied by the Autos with information through organs of sense) of such a kind that these perceptions when synthesized into the objects of nature exhibit that orderly sequence of events which we

find in nature. For this, it would be only necessary that perceptions should be caused in us not by individual events in the mighty Autos, but by vast swarms of such events operating together and producing in us an average effect. And this, on other accounts, seems to be the case (compare, for example, the significant slowness of human thoughts with the swiftness of molecular [events]'). If this view be correct, what are known to us as the [Laws]' of Nature are an outcome from [Laws] of averages among auta. To attempt to penetrate farther lies beyond the scope of the present essay. We must not be tempted to engage here in the study of the little that man is competent to learn about the individual events that are in progress amongst the auta of the sense-compelling part of the universe, or the efficient causes that operate there.

Chapter 19. Recapitulation.

What has been chiefly learned in the foregoing pages is: 1. That the objects of nature are syntheta of perceptions; and 2. That there is no warrant for our assuming that the true autic cause of human perceptions, or of the events that occur among the objects of nature, are in the least like those objects. On the contrary, every evidence that we can collect points to the conclusion that the true source of the perceptions of our egoistic minds, and of those events in nature which are usually attributed to an interaction of the objects of nature upon one another, is in reality as utterly unlike those objects of nature as the thoughts of a man are unlike the events within his brain associated with those thoughts.

These considerations when followed up lead us to reject the common belief in 'material substances' as erroneous, and it is moreover found to be misleading. It is an error which blinds the minds of those who entertain it to the stupendous Autic Universe, which is what really exists, and which transcends the supposed material universe as much as do the boundless range and vast variety of the thoughts of a human mind altogether differ from and infinitely transcend that selection of movements within the brain which accompanies those thoughts.

A theory of existence, such as that which we have sought to expound in this essay, is to be judged, not by the use we are able to make of it, but by its truth. At the same time this theory is far from being useless to the thoughtful student of nature. It becomes

available just at those points where the assumptions usually made by scientific men leave us in the lurch—as when we are brought face to face with the problem of the true relation between a man's thoughts and the events in his brain associated with them; or when the problem is to ascertain of what kind are the true efficient causes of those events that occur about us in nature.

Appendix.

In the foregoing pages the author has freely used passages extracted from others of his writings, altering them and adding to them so as to obviate, as much as in him lay, difficulties which have been felt by some of the readers of those preceding papers; and his hope is that none of these difficulties will be felt in reading the present essay.

The attempt has been made to keep to that one special path through the territory opened up to us by the study of ontology, which pursues its way among the topics of most use to us as scientific students of nature. But much may be learned by other excursions into this great field of exploration, and they end in presenting us with a spectacle of unsurpassed sublimity.

It may be well so far to trespass upon this new ground as to mention some results of the further inquiry. In certain parts of the new territory we have to venture on less firm ground than that which we have trodden in the preceding essay, and must be content with results arrived at with probability. It is then found that such evidence as can be brought to bear appears to tend with considerable emphasis to the conclusion that not only the auta that are our minds are thoughts, but that the same is true of the auta that are our synergos. Now the mind and its synergos are, when taken together, the antitheton or true autic existence corresponding to the objective brain. A similar conclusion is indicated with regard to the rest of objective nature. The antitheta of the objective events —the true autic events which correspond to them—seem, with a considerable degree of probability, to be essentially thoughts; most of them no doubt with vastly different time relations to those of the thoughts that are the human mind, but still in several material respects not unlike them. If this view is correct, the only things that [really] exist are thoughts, and the effects produced by

thoughts upon thoughts; and the laws of averages spoken of above in Chapter 18 are part of a much greater group, viz., the Laws of Thought in general, which if this view is correct are the real ultimate laws of the real universe. It will of cqurse be seen that the laws of thought here spoken of are different and altogether beyond that paltry little group—the laws of human thought—to which they stand related much in the same way as does the whole science of dynamics to the laws of the movements of a watch.

Egoistic thoughts, such as those of the human mind, must be related in the way that we call being within the same consciousness, in order to be able to influence one another. The understanding of the steps of a proof by my mind does not produce any perception of the truth of the conclusion in another mind. The effect and the cause must both be within a group of thoughts that fall within one consciousness. Starting from this, and collecting all the evidence available, we are ultimately led to the conclusion that the Autos, the totality of all thought, is a universal mind, meaning by a mind thoughts related to one another in the way that is described by saying that they are within one consciousness. This, if true, is a very pregnant conclusion, leading on further study to very important results.

Again, the perceptions produced within egoistic minds by sense-compelling auta are an exceedingly trifling part of the great march of autic events, whence but little would be lost out of the great procession if they were discontinued, as would happen if such minds as those of men and animals ceased to be produced. With them, however, the whole 'material' universe, the great objective hypotheton, would come to an end. Similarly, it was created, not at once, but gradually according as the minds that consist of egoistic thoughts by degrees acquired the power of transforming sensations into perceptions, and the power of synthesizing the perceptions into the objects of nature.

Similar reflections meet us at every turn while we are engaged in prosecuting the further investigation; but it would lead us too far from the immediate object of our essay to refer further to them in this necessarily desultory way.

The inquiry on which we have had to enter may be approached either in the skeptical or in the scientific frame of mind. These are not only different but opposed. The motive which rouses the scientific man to exertion is his earnest desire for the increase of

knowledge. For this he is willing to do his utmost in any and every direction that is open to him. The motive which controls the philosophical skeptic is his fear of a false step. He is indisposed to stir at all until secure of his footing. The mind when in a scientific attitude is patient even of known error, if only it can be made the basis of a really good working hypothesis that will help the inquirer forward, and which may then become susceptible of revision and correction. Numberless instances can be given in which this process has led to valuable results. In fact, most of man's scientific knowledge of nature is owing to it. But such a method is repugnant to the philosophical skeptic, whose attitude damps all advance unless it can be carried on from the beginning under conditions of perfection—in other words, under conditions which are impossible in the early stages of almost every inquiry.

30 LEDBURY ROAD, LONDON, W., March, 1903.

HINTS ON THE CLASSIFICATION OF THE ARTHROPODA; THE GROUP A POLYPHYLETIC ONE.

BY ALPHEUS S. PACKARD.

(*Read April 3, 1903.*)

Of the ten or twelve chief groups or phyla into which the animal kingdom is subdivided by systematists, nearly all except those of the old groups Vermes and the Arthropoda are acknowledged to be fairly well limited. There is a general agreement of opinion as to the naturalness and monophyletic origin of the Protozoa, Porifera, Cœlenterata, Echinodermata, Mollusca and Chordata. Those of the "worms" and the great group Arthropoda are still the cause of more or less difference of opinion.

The group Arthropoda was established by Siebold in 1848, but in late years, with the increase in our knowledge of the morphology and embryology of the Arthropodan classes, especially of the Trilobita, Merostomata, Malacopoda (Peripatus) and Myriopoda, there has been expressed by several zoologists the opinion that the Arthropodan phylum is a more or less artificial one, and should be subdivided into more natural groups—*i. e.*, that it is composed of several phyla.

Were it only a matter of convenience, the great group Arthro-

poda might be retained. The fundamental characters are the possession of jointed or polymerous appendages, and the great reduction or entire absence of a cœlomic cavity. Besides this the anterior body-segments are grouped into a head, while the trunk-segments may be either separate and homonomous or differentiated into a thoracic and abdominal region. But it has been pointed out by Kingsley and also by Laurie that the possession of jointed legs in the different classes may be due to convergence, or to homoplasy.

Kingsley and others have shown that the gills and tracheæ are adaptive characters, and that the retention of the groups Branchiata and Tracheata is not warranted. Gills and tracheæ are adaptive features. We have in the phylum Palæopoda the classes of branchiate Trilobita and branchiate Merostomes, while from the latter appear to have evolved the terrestrial tracheate Arachnida. The mode of respiration affords fair class characters, but not phylum characters.

HISTORY OF OPINION AS TO THE POLYPHYLETIC NATURE OF ARTHROPODA.

As early as 1869 the present writer[1] rejected Müller's (1864) and Haeckel's view (1866) that the insects and other tracheates had descended from the zoëa of the Crustacea, and claimed their ancestry from the Annulata. Kennel[2] in 1891 stated his view that the Crustacea arose by an independent line of descent from that of the Annelida, the two groups having diverged from a Preannelidan ancestor, his Protrochosphæra, from which the Mollusca also sprang. The tracheate classes he traces back to the Peripatiformes, from

[1] My views were stated in an article, entitled "The Ancestry of Insects," in the *American Naturalist*, iii, p. 45, March, 1869. In commenting on Haeckel's view that the ancestor of insects, spiders, and myriopods was a zoëa-like form, a view previously expressed by Fritz Müller, and also held by Dohrn, I rejected this theory and suggested that the ancestor of insects and other tracheates "must have been worm-like and aquatic." A little later I referred the ancestry of both the insects and crustacea, "independently of each other, to the worms (Annulata)" (*American Naturalist*, iv, p. 756, February, 1871).

[2] "Die Verwandtschaftverhältnisse der Arthropoden (*Schriften Naturf. Gesells. Dorpat*, vi, 1891). Kennel's view that the Nauplius form originated from the Rotatoria was earlier expressed by the writer, as follows: "The Nauplius form of the embryo or larva of all Crustacea also points back to the worms as their ancestors, the divergence having perhaps originated in the Rotatoria" (*American Naturalist*, v, p. 52, March, 1871).

which Peripatus arose, with two lines of descent, one ending in the Chilopoda and Insecta, the other in Diplopoda, Pauropoda and Symphyla, the branch finally ending in the Arachnoidea. He thus divides the Arthropoda into Branchiata (Crustacea) and Tracheata. He quotes Plate,[1] who in 1889 considered that Crustacea and the Tracheates followed each an "entirely separate developmental path," since he derived the Crustacea from the Rotatoria, and the Tracheata from the Annelida.

In 1883 Kingsley[2] inquired whether the group Arthropoda is a natural one, calling attention to the fact that the insects have been derived from Peripatus, while the Crustacea "had an ancestor resembling the Nauplius of the Phyllopoda or the Copepoda." In 1894[3] he divided the Arthropoda into three subphyla: I. Branchiata; II. Insecta or Antennata, and III. Diplopoda, rejecting the old grouping into Branchiates and Tracheates (though retaining the Branchiata), and he states his belief that the three divisions he makes "are but remotely related to one another, and it may yet be proved that they have no common ancestor nearer than the Annelids."

Indeed, as early as 1886, A. C. Oudemans[4] thus expressed his views as to the relations of Limulus with the trilobites, and of the derivation of the scorpion from the Eurypterida: "Though some zoologists doubt the relationship of Limulus with the Trilobita, the paleontologists have long ago been convinced of it. Among the numberless Trilobita there occur all possible transition forms between them and Limulus, and to Scorpio the Eurypterida form a partial bridge." His genealogical tree represents the Xiphosura as originating from the trilobites and the scorpions as derived from the Eurypterida, in this respect theoretically anticipating the results attained by Pocock with Palæophonus. Oudemans also acknowledges the close resemblance of trilobite larvæ to that of Limulus.

[1] "Ueber die Rotatorien fauna des bottnischen Meerbusens, nebst Beiträgen zur Kenntniss der Anatomie der Philodiniden und der systematischen Stellung der Räderthiere" (*Zeitschrift f. Wissen. Zoologie*, xlix, December, 1889).

[2] *American Naturalist*, xvii, p. 1034, 1883.

[3] *American Naturalist*, xxviii, pp. 118 and 220, 1894.

[4] "Die gegenseitige Verwandschaft, Abstammung und Classification der so-gennanten Arthropoden" (*Tijdschr. d. Nederland. Dierk. Vereen*, 2e Ser. Deel 1, 1886).

I also stated in 1893[1] that there are four lines of development in the Arthropoda (throwing out for the present the Linguatulina and Tardigrada), viz.: "the Podostomatous line, the first to be struck off from the Annelidan stock (the trilobites being the first forms to appear); second, the Arachnidan line; third, the Crustacean line, nearly coeval with the first or Podostomatous; and the fourth, the line culminating in Myriopods, Scolopendrella and insects; and it is safe to suppose that the terrestrial tracheate groups of Arachnida, Myriopoda and insects were later products than the marine, aquatic branchiate classes—*i. e.*, the Podostomata and the Crustacea."

Afterwards in 1898, in my *Text-Book of Entomology*, as a result of the memoirs of Lankester, Kingsley, and the work of Kishinyoue on the embryology of the Japanese Limulus, from morphological and embryological data, having abandoned earlier opinions as to the Crustacean affinities of Limulus, I gradually was led to recognize the close affinity of the Merostomes and Arachnida, stating that the embryology of Limulus and Arachnida "shows that they have descended from forms related to Limulus, possibly having had an origin in common with that animal, or having, as some authors claim, directly diverged from some primitive eurypteroid merostome" (p. 6). Again, on p. 8: "The Arachnida probably descended from marine merostomes, and not from an independent annelid ancestry." Again, on p. 3, in a discussion of the relation of insects to other Arthropoda: "It is becoming evident, however, that there was no common ancestor of the Arthropoda as a whole, and that the group is a polyphyletic one. Hence, though a convenient group, it is a somewhat artificial one, and may eventually be dismembered into at least three or four phyla or branches."

Subdivision of the Arthropoda into five Phyla.—I would suggest the following grouping of the principal classes of the Arthropoda, beginning with what may be regarded as the most primitive assemblage of classes, and for which I would propose the name *Palæopoda*, in allusion to the very primitive and homonomous nature of their post-antennal or post-oral appendages, when compared with those of

[1] "Further Studies on the Brain of Limulus Polyphemus, with Notes on its Embryology" (*Memoirs Nat. Acad. Sciences*, p. 322, 1893). Compare also *Zoologischer Anzeiger*, April 20, 1891.

the Crustacea.[1] I also add what appear to be the essential characters of the phylum.

Phylum I. PALÆOPODA. Composed of three classes—*i. e.*, *Trilobita*, *Merostomata*, *Arachnida*.

Body trilobate (in Trilobita and many Merostomata), never protected by a true carapace, composed of a head and trunk region; the head-region separate from the trunk, in Trilobites (Triarthrus) composed of (judging by the appendages) five segments (somites, arthromeres), in Merostomes six, while in Arachnida the head fused with the so-called thorax (cephalo-thorax) also consists of six segments. The first pair of head-appendages, in a single trilobitic genus (Triarthrus), are long, slender, uniaxial and antenniform, or biramose, chelate (Merostomata and Arachnida); all the post-oral appendages, in the most primitive class (Trilobita), biramose, consisting of an outer and inner many-jointed division, but all homonomous, or retaining the same fundamental and primitive shape from the mouth to the end of the body, and never (as they are in Crustacea) differentiated into true or functional mandibles, maxillæ, maxillipedes, ambulatory uniaxial thoracic legs, or biramose abdominal limbs. The gnathobases, or coxal joint of each limb, especially those near the mouth, armed with inward projecting spines, acting as jaws to tear and to keep the food or prey from escaping. In the Merostomata the post-cephalic or trunk (abdominal) limbs biramose and adapted for swimming, and either (in Trilobites) expanded posteriorly and probably serving both for swimming and respiration, or in Merostomes (*Limulus*) bearing on the exopodite of each limb, except those of the first pair, a pile of numerous gill-sacs. In Arachnida, in adaptation to a terrestrial life, the six pairs of abdominal or trunk limbs are reduced, mostly atrophied, represented in the scorpion by the pectines and the four pairs of invaginated book-lungs, and in spiders by the two pairs of book-lungs (Mygale) and the three pairs of spinnerets, which are 2–3 jointed, external free appendages. A hypostoma is present and well developed in Trilobita and Merostomata, as also a double underlip, the chilaria of Limulus.

The eyes of Asaphus, etc., and of Limulus are compound, al-

[1] Palæocarida was proposed when I believed that Limulus and its allies were Crustacea; my name Podostomata was proposed for a group embracing the two classes Trilobita and Merostomes; the present name, Palæopoda, is needed to embrace the three classes mentioned.

ways sessile, and distinguished by the thick, either lenticular or long conical lenses, arranged in quincunx order.

The integument is chitinous, insoluble as in insects, never containing carbonate or phosphate of lime, or forming a solid crust as in the higher Crustacea. The cartilaginous plate (endosternite), so large and well developed in Limulus, is also present in Arachnida.

In the living forms (Limulus and Arachnida) the digestive canal may be differentiated into a slender œsophagus, a proventriculus armed with rows of numerous chitinous teeth (Limulus) and an intestine, the stomach being but slightly differentiated. The liver or hepato-pancreas is large and voluminous. In the Merostomes (Limulus) there are no salivary glands, though occurring in Arachnida. Genital openings always (Merostomata and Arachnida) prosogoneate, the oviducts or seminal ducts opening out separately on the posterior aspect of the basal abdominal limbs (Limulus), or in Arachnida united into a single terminal passage, opening by a single orifice at the base of the abdomen. In the marine forms, with gills or localized respiration, the heart is tubular and the arterial system remarkably developed and finely divided, whereas in the tracheate, terrestrial forms the arteries and veins are absent, respiration being carried on throughout the body (chiefly abdominal) cavity.

In the Palæopoda there is no true metamorphosis like that of the Crustacea, no nauplius or zoëa stage. The first or earliest larval stage, the *protaspis*[1] stage of Beecher, can, so far as we can see, in no way be likened to the nauplius of a crustacean. The nauplius has an oval body, not differentiated into segments, but with three pairs of slender swimming limbs, which finally become the two pairs of antennæ and the mandibles of the adult. In the protaspis of trilobites, as defined by Beecher, the conditions are entirely different and such as suggest the origin from a polymerous Annelid ancestor. The minute disk-like or suborbicular larva of different genera of Trilobites described by Barrande and by Beecher consist of two regions, a head and trunk or abdomen. There are in the head indications of five annulations, the same number as in the adult Triarthrus; the much shorter abdominal region has from "one

[1] This term was proposed by Beecher in his paper on "The Larval Stages of Trilobites" (*Amer. Geologist*, September, 1895). Previously to that, A. C. Oudemans, in 1886, in the article cited, proposed the name *Proagnostus* for the same stage. If used, this name might be amended to read Protagnostus stage.

to several annulations," which probably represent segments. From this we logically infer that in the protaspis of trilobites there were more than three pairs of head-appendages, and possibly two or three pairs of abdominal appendages. Now the larva of Limulus is hatched with two body-regions, of the same general shape as those of the trilobites, and it is also trilobed; the embryo, sometimes before hatching, with its thick spherical body, strongly recalls the protaspis stage of trilobites, and seems to justify the view that the freshly hatched larva of Limulus is a protaspis.[1] In the protaspis-like fossil Cyclus, which seems to represent an ancestral type of Limuloids persisting into the Carboniferous Period, there are traces of head-appendages like those of the embryo Limulus.

The metamorphosis of the Palæopoda is, then, incomplete; the limbs of the protaspis retain the form and functions of the larva, the adult simply differing in acquiring at successive molts additional trunk-segments, with their corresponding limbs.

The eggs of Limulus as well as of Arachnida are large and not so numerous as in some Crustacea; those of Limulus are laid in the sand. The eggs of trilobites are also large, spherical, and evidently, like those of Limulus, were deposited in the sand or sandy mud, as they occur separately from the trilobites themselves.

The embryology of Limulus presents some unique features, and yet there is such a close resemblance to that of the scorpion that the embryology of the Arachnida, as I have freely acknowledged, affords very strong proofs of their relationship to and descent from merostomes. In the embryo of the scorpion and spiders there are six pairs of head- (cephalothoracic) appendages, and the mode of origin of the book-lungs of the scorpion and spiders seems to prove that they are derivatives of the exopodites of the abdominal limbs of Limulus.

It results from what is now known of the structure of the Trilo-

[1] I freely acknowledge that many years ago (1872) I supposed that the embryo Limulus passed through a nauplius, and that I called it a "subzoëa stage," but this view was long since abandoned, as also my contention that Limulus was nearer the Crustacea than the Arachnida. It need hardly be added that while as previously I cannot agree with the view that Limulus is an actual Arachnid, it has for some years, through the result of the work of Kingsley and Kishinyoue, been evident that the Merostomes are closely related to the Arachnida, and I adopted this view in my memoir on the brain of Limulus (1893).

bita that they have no relationship with the Crustacea. To include them in that group, otherwise a most natural one, is not good taxonomy. The chief characters which are given for retaining the Trilobita as a primitive group of Crustacea are the presence of the antennæ-like preoral appendages of Triarthrus and one or two other genera. That this is not so important as might seem at first sight is the presence of four antennæ-like appendages in the head of Eurypterus; Holm having discovered that the first pair are chelate, like those of Limulus.

Both Trilobita and Crustacea have biramose limbs, adapted for swimming, but so has any marine arthropod; the fact that the limbs are divided is the result of their inheritance in either class from Annelids with parapodia, but in the multiarticulate structure of each ramus and the entire lack of differentiation of the whole series of postoral limbs in Triarthrus we have fundamental characters which are diagnostic of the Trilobites, and widely separate the class from the Crustacea. Whether the Merostomata are widely distinct from the Trilobita or not, we submit that it is a mistake to include the latter in the class of Crustacea.

Entirely disagreeing with those who widely separate the Merostomata from the Trilobites, after repeatedly going over the subject, the close relationship of the two groups seems to us to be very apparent, the differences being only such as would separate the two classes of a single phylum. It has seemed to us that the merostomes and trilobites either had a common ancestry, which was a protaspid, or the Merostomes by way of the Synxiphosura diverged from the trilobite stem after it had been established in Precambrian times. Thus far, unfortunately, we know nothing of the nepionic stage of any of the Eurypterida. Their earliest adult form (Strabops of Beecher[1]) occurs in the Cambrian, while the Synxiphosura date from the Silurian. It is not improbable that some genus of this group gave origin to the Xiphosura. On the other hand, is there not so close a resemblance between some of these Synxiphosura, such as Neolimulus and Bunodes, as to suggest that the Merostomes are direct descendants of the Trilobita? If we compare the figures

[1] Although Beecher refers this early form to the Eurypterida, it appears, judging from his figure, to quite as much resemble certain Synxiphosura, as Bunodes and Neolimulus, in the short, broad head and shape of the trunk-segment and telson, though it has two segments more than in the Synxiphosura and one segment less than in the Eurypterida.

of *Aglaspis eatoni* with that of Dalmanites (Figs. 1414 and 1331 of Zittell-Eastman's *Paleontology*), is there not such a close resemblance in the shape of the head (or cephalothorax) and of the trunk-segments as to suggest a close alliance, even though members of two distinct classes? To answer this question by saying that this is a case of convergence, the objector might be referred to the other Synxiphosura, which also suggest a common origin of the two classes from a protaspis ancestor. It has been suggested that some of the Cyclidæ are larval Eurypterida or Limuloids; if this should prove to be the case (of which we are by no means sure, as no Cyclidæ have yet been found below the Carboniferous), we should have an additional argument for the common origin of the two classes, for the Cyclidæ somewhat resemble the larval trilobites.

Relation between the Merostomata and Arachnida.—While we have from the first maintained that the Merostomes should not actually be included among the Arachnida—*i. e.*, that Limulus is not a genuine Arachnidan, as claimed by Van Beneden, Lankester and later authors—from the evidence we now have as to the mode of origin of the book-lungs and the morphogeny of the appendages in general, and especially the interesting and remarkable discovery by Mr. Pocock,[1] that the Silurian so-called scorpions are probably marine links between scorpions and Eurypterida, whatever objections I have formerly expressed to their Arachnidan affinities are now overcome, and it seems plain that the scorpion is a direct descendant of some Eurypteridan. Pocock's fortunate discovery in the Silurian scorpion (*Palæophonus hunteri*) of the inner branch of a two-jointed appendage, which appears to be the homologue of a recent scorpion's "pecten," should it be confirmed by the discovery of additional examples; as well as the thickness of the head-appendages, the last four pairs of which end in a single point, not in claws, as in modern scorpions—these discoveries appear to give the clue to the line of descent of Arachnida from some Merostome, one would say from some Eurypterus-like form, though, from other features observed by him, Mr. Pocock takes the view that "Palæophonus occupies an intermediate position between Limulus and the Eurypterida on the one hand and recent scorpions on the other, standing, if anything, rather nearer to the former than to the latter."

[1] "The Scottish Silurian Scorpion," *Quart. Journ. Micr. Sc.*, Vol. 44, n. s., 1902.

We quite agree with Pocock's opinion that Palæophonus was not adapted for land and aërial respiration, but "lived in the sea, probably in shallow water, its strong, sharply-pointed legs being fitted for maintaining a secure hold on the bottom."

In conclusion, then, we would suggest, from our present knowledge of the Palæopoda, that the group is a natural one, that the line of descent of the phylum from some Annelid-like worm was independent of that of the crustacean phylum, and that the affinities shown by morphology and embryology to exist between the Trilobita, Merostomata and Arachnida are so close that they form a tolerably definite series of interrelated classes.

Phylum II. PANCARIDA. Represented by a single class, *Crustacea*. The phylum name is proposed for the reason that the group is so well circumscribed, none but the genuine Crustacea or Carides belonging to it, forms as to whose position in nature all zoologists are well agreed.

In this group there is a decided advance over the Palæopoda in the differentiation of the appendages into from three to six kinds, with corresponding functions. In the lower or more primitive, though somewhat modified, group of Cladocera, such as Daphnia, there are two pairs of antennæ, a pair of mandibles, of maxillæ, and of legs or trunk-appendages, the whole performing four different functions; while in the Decapoda there are besides the antennæ, mandibles and maxillæ, three pairs of maxillipedes, five pairs of thoracic and six of abdominal legs, or appendages, in all performing six different kinds of functions—a degree of differentiation and specialization not exceeded by any other Arthropodan group.

The members of the phylum show an increasing tendency, as we rise towards the more specialized forms, to a heteronomous segmentation and also to a wonderful transfer of parts headwards (cephalization), the cephalothorax being covered by a carapace formed by the hypertrophy or excessive development of the tergites of the second antennal and mandibular segments. In the Phyllocarida the cephalothorax is covered by a bivalvular carapace, with a weak adductor muscle; while in Apus it, in adaptation to its burrowing in soft mud, assumes the general shape of the shield of Limulus; while in the Estheridæ the entire body is protected by the two valves, which are connected by a definite hinge and ligament. On the other hand, the head-shield of the Palæopoda, as well as the pygidium when occurring, is the result of the simple fusion of the

segments. While the Phyllopoda are generally regarded as the most primitive group—their swimming limbs closely resembling those of Annelid worms—it may be questioned whether the Phyllocarida are not a still more primitive group; certainly they are the most composite or synthetic, and were the earliest known group of Crustacea.

Crustacea are, like the Palæopoda, prosogoneate; but when we take into account the fact that there is in the adult but a single pair of nephridia (the green gland), or in other forms (Phyllopoda) the shell gland, there has been a great reduction in the number of pairs from what may have been the ancestral type, while Limulus still retains four pairs. In all Crustacea the eggs are carried attached to the body of the parent, and never, as in trilobites and merostomes, deposited loosely in the sand.

In their metamorphosis, which is a complete one in all the typical forms, the larval stage of the lower Crustacea being a nauplius, we have another feature wanting in the Palæopoda. As is well known, the early embryo of Moina passes through a prenauplian stage like that of Annelida, and the indications are that the nauplius is itself a derivation from the trochosphæra stage of Annelid worms.

Now, as is well known, the most primitive groups or members of a group do not undergo transformations; and in this respect the Pancarida are a later, more specialized group than the Palæopoda. It will be remembered that the most primitive insects (Synaptera) do not undergo a metamorphosis, and in several of the lower orders of winged insects it is incomplete, there being no larval and pupal stages; in the Arachnida only the extremely modified Acarina undergo a slight metamorphosis. That of the Meropoda is slight.

Enough has been stated, we think, to show that the Palæopoda are quite remote from the Pancarida, and that a union of the trilobites in the same class with the Crustacea brings about an unnatural association, and tends to an unnecessary amount of confusion.

Dr. Kingsley regards the Trilobita as the more primitive subclass of Crustacea, but we are unable to see any features in Crustacea which could have been derived from trilobites; there are no transitional forms, and the larval forms are widely distinct, as he has well shown. The gap between the two groups is, on morphological and embryological grounds, a very wide one. Already in the early Cambrian seas trilobites were a predominant type, while

the Crustacea were comparatively scanty in numbers, and represented by primitive types showing no trace of trilobite characters.

The Chief Factors in the Evolution of Classes.—Assuming that the Arachnida, represented by the most typical form, the scorpion, have evolved from the class of merostomes, in the way suggested by Pocock, the entire process or phenomenon has the most direct and instructive bearings on the method of evolution of one class from another.

In the first place, the single group of scorpions—say a single generic form—appears to have arisen from some genus of Eurypterida, allied to Eurypterus, and by divergent evolution the great class of Arachnida, with its eight orders, appears to have originated by one step after another from a single type, not necessarily an individual, but many, all the members of the genus being modified by similar causes, in the same manner and at the same time.

The modification of a marine Eurypteroid form, perhaps living in a shallow, land-locked basin, perhaps finally becoming brackish, into a terrestrial scorpion, was due to changes in the environment, in the topography; this reacted on the Eurypterid and resulted in change of habits, and consequent adaptation to brackish, and perhaps to fresh, water, and finally to land. With little doubt, all the forms inhabiting the area underwent the same kind of modification and similar adaptation to a new medium, the same changes of function resulting in the disuse of organs adapted for marine existence and the evolution of structures adapting the animal for terrestrial life.

The changes by which the connecting links (Palæophonus) became transformed into a genuine scorpion, the ancestor and founder of the Arachnida, were the following:

1. The loss by disuse of the abdominal swimming appendages (except the pectines), and the ingrowth and reduction by disuse of the expodites, the gills attached to them being carried in, forming eventually the book-lungs of the scorpion, each with its spiracular opening, adapted for aërial respiration.

2. The four hinder pairs of cephalothoracic appendages became slenderer after the animal had left the water and adopted a life on land, under stones or the bark of trees, etc., and the single stout claw of the original Palæophonus became by use, in climbing trees, etc., two-clawed, like those of all Arachnida and insects.

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3. The compound eyes of the Merostomes became broken up into groups of single eyes.

4. Most remarkable changes took place in the internal organs, resulting in the development of salivary glands, none occurring in Crustacea and other marine Arthropods.

5. The acquisition of Malphigian or urinary tubes which exist in terrestrial Arthropods, Arachnida, insects, etc., but in no marine Arthropods.

6. A gradual reduction in the number of pairs of nephridia, all Arachnida having but a single pair, Limulus having four pairs, and the Eurypterida presumably as many.

7. After the scorpion type became fixed and the spiders arose, the number of pairs of book-lungs became reduced from two pairs in Mygale to one in other spiders, and then began an evolution of tracheæ from dermal glands—a process seen in certain terrestrial planarian worms as well as land-leeches.

8. While the arterial system of Limulus, owing to its localized organs of respiration, is remarkably developed, in the scorpion the arterial system is greatly reduced, and in the tracheate Arachnida, such as the spiders, there are no arteries or venous lacunæ.

It is most probable that the evolution of the Palæophonus descendants, viz., the scorpions of the Carboniferous—assuming that they were true scorpions—took place with comparative rapidity, *i. e.*, by tachygenesis, without the extremely slow method postulated by the natural selectionists, the modification suggested above having contemporaneously affected all the individuals, many thousands or tens of thousands alike. The method was not, as Darwin imagined, the result of a single chance variation gradually and by numberless intermediate forms passing into a species which gave origin to many others, from which were gradually evolved new subgenera, genera, subfamilies and so on, but the method was radically different. The Palæophonus, an Eurypterid, became, we take it, in a comparatively few generations the parent of a scorpion, the representative of a distinct class. The class characters, great as are the differences, especially in its internal organs, between an Arachnid and a Merostome, were assumed with comparative suddenness. New classes, like new species, did not arise from a single but from a large number of individuals. This was Lamarck's doctrine, and it has been reaffirmed by De Vries. This shows that even classes

are in a degree artificial or ideal conceptions. And so it was with the evolution of mammals from theromorphous reptiles, and of birds such as the Archæopteryx from reptiles. With our present knowledge we can trace an almost exact parallel between the tachygenic origin, by change in the medium, inducing changes in habits and the functions, of flying in sectsfrom Synapterous forms, that of the Arachnida from the Merostomes, of Amphibia from Ganoid fishes, of reptiles possibly from Amphibia like the Labyrinthodonts, of birds from dinosaurian reptiles, and of mammals from theromorph reptiles (unless the Amphibians, as some contend, were the source of mammalian life).

The exciting causes of the differentiation of classes, as well as orders, families and genera, were geological and topographic changes, enforced migration and consequent isolation, adaptation to a new medium, to new conditions of life, such as a change from marine to fresh water, from fresh water to land, and in the case of pterodactyls, birds and insects, from a terrestrial life to one spent partly in the air.

The early Paleozoic ages as well as the Precambrian were periods of the rapid evolution of phyla, and of class and ordinal types, as shown by Hyatt, the writer, and others. Indeed, it would seem as if the evolution and differentiation of varieties and species succeeded rather than preceded the formation of genera and higher groups. It may be questioned whether the natural selectionists could make any progress in evolution, so to speak, by beginning with merely simple variations, although after the higher or more general groups were originated, and this was by far the most difficult and important step, specific variations set in very rapidly, as early as Cambrian times. Few, except palæontologists, appear to appreciate the rapidity with which evolution in Precambrian and Cambrian times must have operated among the plastic forms which here and there crowded the early paleozoic seas.

Phylum III. MEROPODA. This group is proposed to include the classes of *Pauropoda*, *Diplopoda* and *Symphyla*.

Prosogoneate myriopods, in which the body is in the typical forms cylindrical, the trunk-segments variable in number, but usually numerous, and each segment "double"—*i. e.*, united by a dorsal plate, which was originally two plates which had been fused together (Heathcote), unless we adopt the views of Kenyon that the alternate plates disappeared, the remaining plates overgrow-

ing those behind them, so as to give rise to the anomalous double segments; the feet arise close together along the median line of the body, there being no sternal plates between them. In the typical Diplopoda the head consists of three segments, the preoral or antennal and two postoral, bearing the mandibles (protomalæ) and the single pair of maxillæ (deutomalæ) united to form the gnathochilarium or underlip. As all the members of this phylum agree in having from two- to three-jointed mandibles, in which respect they differ from Chilopod Myriopods and especially insects, we have given the name *Meropoda* to this phylum in allusion to the primitive nature of these appendages, which resemble the maxillæ rather than the mandibles of insects.[1] The mandibles of the Diplopods consist of three segments, a basal segment (cardo), a middle segment (stipes), and a distal one (mala mandibularis), which supports two lobes homologous with the galea and lacinia of the maxilla of an insect. Diplopods are also provided with eversible coxal glands, in position like those of Scolopendrella; these perhaps functioning as blood-gills, and in Lysiopetalum occurring between the coxæ of the third to sixteenth pair of limbs.

A primitive feature, and the one diagnostic of the Meropoda as compared with the Chilopodous Myriopods, is the paired genital ducts and openings which are situated near the head between the second and third pair of legs. In the Symphyla the opening is single, proving the later origin of that group. Another diagnostic feature is that the male genital glands lie beneath, while in Peripatus, Chilopods and insects they lie above the digestive canal.

The tracheary system is also more primitive than in Chilopoda and insects, the tracheæ not being branched (except in Glomeridæ) and anastomosing, and the tracheæ themselves are without spiral threads (tænidia). In Diplopods the stigmata, which are permanently open, are placed beneath the legs, or even in the coxal joints. The nervous system is much more primitive than in Chilopoda and insects. The external genital armature, a complicated apparatus of male claspers and hooks, apparently arises from the sternum of the sixth trunk-segment, and they are modifications of the seventh pair of legs.

In their embryology the Diplopoda are more primitive than the

[1] There is an approach to this trimerous condition in Thysanura and Orthoptera (Blatta) and certain Coleoptera (see my *Text-Book of Entomology*, p. 60, also p. 12).

Chilopoda. In Polydesmus the method of formation of the blastoderm more resembles that of the Crustaceans and Arachnida than that of Chilopods.

The larva of the Diplopods, though bearing but three pairs of legs, differs from that of any insect in that these limbs are not appended to consecutive segments; either the second or the third segment in different species of Julus being legless, while in Blaniulus the legs are borne on segments 2 to 4 behind the head.[1] The new double segments with their two pairs of legs arise at successive molts, so that the animal undergoes a partial metamorphosis; while the Chilopods are hatched in the form of the adult, being polypodous.

PAUROPODA. Nothing has been added to our knowledge of these forms since the publication of the thorough works on them by Kenyon and by Schmidt.

The group was regarded as an order (Pauropoda) by Lubbock. Kenyon, however, created the order *Protodiplopoda*, including in it Pauropus and Polyxenus.

The Pauropoda are regarded by Kenyon as degenerate Diplopods, owing to the absence of tracheal and circulatory systems, and distantly related to Polyxenus; on the other hand, the simplicity of the segmentation, the fact that there is but a single pair of legs to a segment, and other features pointed out by Kenyon, lead us to provisionally regard the group as a class more primitive and distinct from the Diplopoda. The number of mouth-appendages is the same as in the Diplopods; the genital aperture opens on the third trunk-segment, and the testis is situated above the intestine (the ovary below).

History of the Opinions regarding the Taxonomy of the Meropoda.—The first writer to doubt the naturalness of the group Myriopoda, and to state that the Chilopoda and Hexapoda were more nearly allied than the Chilopoda and Diplopoda, was Pocock,[2] in 1887. A year later Dr. Kingsley[3] arrived independently at the same opinion, adding the anatomical data in support of this view.

[1] The young of Polyzonium, however, is hatched with four pairs of legs, borne on each of the first four trunk-segments (Rimsky-Korsakow, *Travaux Soc. Imp. Naturalistes de St. Petersbourg*, XXV, 1895, Pl. 1, Fig. 8).

[2] *Annals and Mag. Nat. Hist.*, XX, October, 1887.

[3] *American Naturalist*, December, 1888, p. 1118.

In 1893 Pocock [1] divided the tracheate Arthropods into two sections, the *Progoneata* (including class Pauropoda and class Diplopoda), and *Opisthogoneata*, embracing the Homopoda (class Symphyla and class Chilopoda) and Hexopoda (class Hexopoda). Afterwards [2] he placed the Symphyla among the tracheate Progoneata.

This classification of Myriopoda was adopted by Schmidt in 1895, and has been adopted by Verhoeff [3] and the term Myriopoda will probably hereafter be merely used as a convenient appellation for polypod tracheate arthropods.

We would add that, rejecting the old term Tracheata, the prosogoneate Myriopods appear to us to constitute an independent phylum, rather than a subphylum, and for that reason we have ventured to propose the name *Meropoda* for the group (μερος, a part or segment; πους, ποδος, a leg), from the fact that the mandibles are more distinctly divided into segments than in any other group of Arthropods, thus more closely resembling the other appendages of the body, whence it follows that all the limbs, including the mandibles, have the primitive feature of being composed of several segments.

The Symphyla in respect to the structure of the mandibles are less primitive than the Diplopods, but I am now inclined to agree with those who have pointed out their Diplopods affinities and to place them among the Meropods.

The Systematic Position of the Symphyla.—This is a puzzling problem. In my *Text-Book of Entomology* I have with some care reviewed the chief points in the anatomy of Scolopendrella and the opinions of different authors regarding its systematic relations. Having studied sections of the animals, I prepared a figure or reproduction from the sagittal sections of a female, of which the accompanying illustration (Fig. 1) is an enlarged reproduction.

Comparing the digestive tract with that of Pauropus, it is divided into three portions; the œsophageal valve opening into the stomach is seen at *œ. v.*, and the beginning of the rectum is well marked; the two urinary tubes are large, arising at the posterior end of the intestine and ending in front at the third segment from the head

[1] *Zoologische Anzeiger*, xvi, Jahrg. 3, Juli, 1893, p. 271.

[2] *Natural Science*, x, February, 1897, p. 114.

[3] Bronn's *Klassen. u. ord. Thier-reichs*, Bd. V, VI, Abth. Arthropoda, Leipzig, 1902.

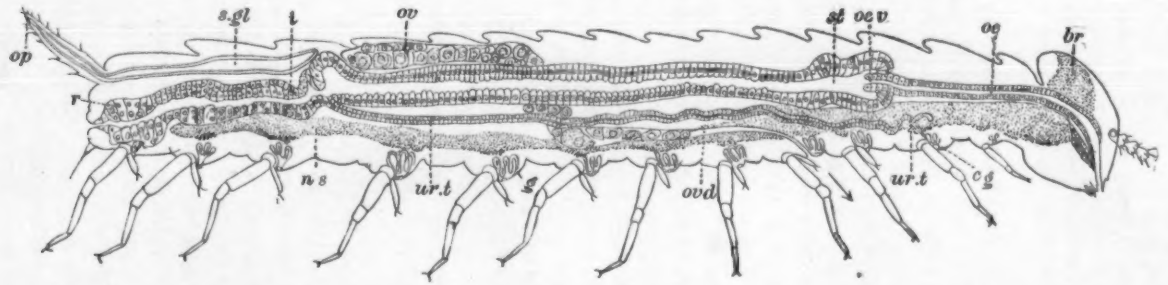


FIG. 1. Section through *Scolopendrella immaculata*; *œ*, œsophagus; *œ.v*, œsophageal valve entering the stomach; *i*, intestine; *r*, rectum; *br*, brain; *ns*, abdominal chain of ganglia; *ovd*, oviduct; *ov*, ovary; *s.gl*, silk gland, and *op*, its outer opening in the cercus; *ur. t*, urinary tube; *cg*, coxal glands or blood-gills.—Author, *del.*

(*ur. t.*). The ovary (*ov.*) is seen to lie partly beneath but mainly above the intestine; the median opening of the oviduct (*ovd.*) being indicated by the arrow between the third and fourth pair of legs. Attention should be called to the eversible coxal sacs (*c. g.*), of which there are eleven pairs situated at the base of the legs of each pair; the sac is largest and most developed in the middle of the body and is a convoluted tube which makes three turns. The silk gland (*s. gl.*) at the end of the body is large, its direct opening situated at the end of the cercus, while the gland itself extends as far forward as the third segment from the end of the body. The brain and nerve-cord are large and thick, much as in Pauropus. The dorsal vessel, fat body, rectal glands and the salivary glands are not represented.

There is in Scolopendrella a mixture of Diplopod and Thysanuran characters, the former the more primitive and predominating. My original idea that it is a Thysanuran is certainly a mistaken one. The Symphyla evidently forms a group by itself, and I am inclined to agree with Pocock and with Kingsley that it should for the present be associated with Pauropods and Diplopods. Yet were it not for the anterior position of the genital opening we should regard it as the representative of a group from which the insects have descended.

The Symphyla is evidently a much less primitive group than the Pauropoda and Diplopoda, as proved by the single genital opening and the Thysanuran characters it possesses. It would seem as if it had already begun to diverge from the Diplopod stem, and was becoming modified in the direction of the Thysanura.[1] It is a true composite or prophetic type which has persisted from very early paleozoic times, and we may well imagine that there once existed a form intermediate between it and the Thysanura in which the genital outlet had moved back to the position it holds in Chilopods and insects. As I state in my *Text-Book of Entomology*, "certainly Scolopendrella is the only extant Arthropod which, with the

[1] The thysanurous characters and the fact that it has but a single pair of legs to a segment (unless, as Schmidt suggests, the parapodia "represent the vestiges of a second pair of legs and correspond to the hinder pair of limbs of the primary double segment," thus indicating I would add the diplopod origin of Scolopendrella) appear to indicate that it is a form which has become considerably detached from the Diplopod stem, and has gone part way towards the incoming Thysanura. Campodea also possesses these so-called "parapodia."

sole exception of the anteriorly situated genital opening, fulfills the conditions required of an ancestor of Thysanura, and through them of the winged insects" (p. 22). Meanwhile, until the embryology of this form is thoroughly worked out and compared with that of the Diplopods on the one hand, and Campodea, as treated by Uzel, on the other, we must be content to let the Symphyla remain provisionally associated with the Diplopoda in the phylum Meropoda.

Phylum IV. PROTRACHEATA. Class *Malacopoda*. The arthropodan features of Peripatus are discussed in my *Text-Book of Entomology* (p. 9). Its nature as the probable ancestor of the Chilopoda is, notwithstanding the immense gap between it and Chilopods and insects, such as to still compel us to suppose that it resembles the probable progenitor of the Chilopods and of the insects. It would be difficult to know what better to do with it. It certainly cannot be placed among the Annelids, or in any other Arthropodan phylum, and it is with little doubt a very ancient type which has persisted from perhaps early paleozoic times.

Phylum V. ENTOMOPTERA. Class *Chilopoda* and class *Insecta* (Hexapoda). While the Chilopoda are the nearest allies of the Insects, there is certainly a wide gap between them, and there are no structures in insects which unmistakably point to their origin from Chilopods, although Uzel in his account of the embryology of Campodea shows that in some respects it develops like Geophilus. At present, however, we are in the dark as to the origin of the thysanurous Synaptera from any form, unless we invoke a Scolopendrella-like ancestor in which the genital opening has moved back to a position homologous with that of Peripatus, Chilopods and insects.

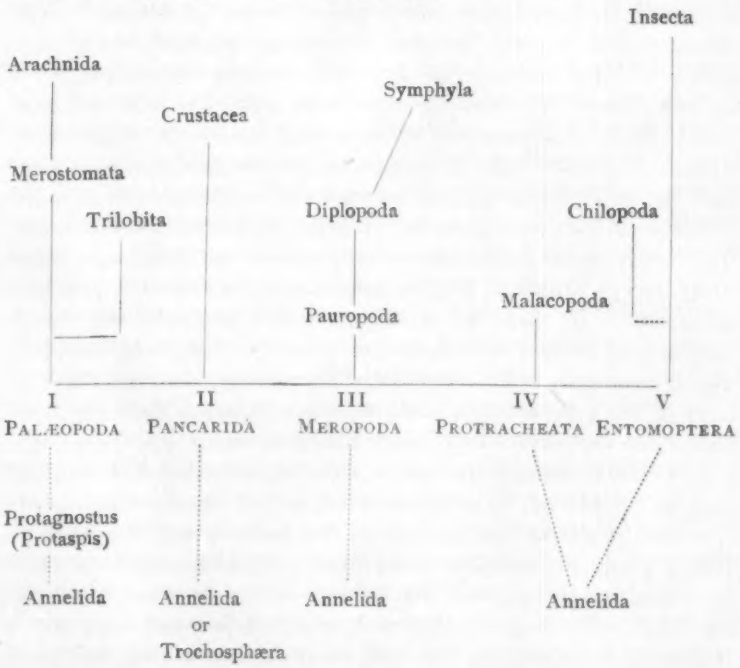
The combination of Chilopoda and Insecta as here given is a new one,[1] and for the Phylum, as we limit it, a new name seems necessary. As the Chilopods are a quite subordinate group, and the great mass of the orders is composed of winged forms, I have ventured to propose the term *Entomoptera* to cover this great group of Arthropodous animals, reserving the name Insecta for the class which has always borne that name. Each of the phyla as here limited appears, judging from their structure and what we know of their development, to represent distinct and independent lines of development, and are submitted for consideration by zoologists. It

[1] The *Antennata* of Lang comprises all the Myriopoda and the Insects.

may at least be claimed that the breaking up of the Arthropoda into more definite, well-circumscribed groups will lead to greater exactitude and definiteness when referring to them.

After this article was completed I discovered that A. C. Oudemans as early as 1886 thus expressed his views as to the naturalness of the Arthropoda: "It is desirable that the group of Arthropoda should be given up. The groups of Acaroidea, Arachnoidea, Crustacea, Pantopoda, Onychophora, and Insecta are independent of each other, and should, therefore, be treated separately in the manuals. The very complicated structure would then become clearer to the student. A comparison of the groups with each can best take place afterwards and not beforehand" (*l. c.*, p. 20).

The following diagram will roughly indicate the different Phyla and the principal classes into which they are divided. It should be observed that the Annelidan ancestors of any of these five Phyla probably had few trunk-segments, being probably primitive Trochozoa with parapodia already developed.



PROVIDENCE, R. I., March 28, 1903.

THE PRINCIPLE OF LEAST WORK IN MECHANICS AND ITS USE IN INVESTIGATIONS REGARDING THE ETHER OF SPACE.

BY MANSFIELD MERRIMAN.

(*Read April 2, 1903.*)

The principle of least work has been extensively used in applied mechanics since 1879, when it was first formally stated and established by Castigliano. Previous to that time, various authors had discussed the principles of least action, of least constraint, and of least resistance, and had applied them in the solution of special problems. The principle of least work, however, is capable of more definite statement and demonstration than the other minimum laws, and its range of application in statical investigations on elastic structures is wide, while it has been found to be of great practical value to civil engineers.

When a structure like a bridge truss contains members sufficient to prevent distortion of its panels and no more, the stresses in these members due to given loads can be readily computed by the principles of rigid statics, the members in this case being called necessary ones. If there be superfluous members, however, rigid statics cannot determine the stresses, since the number of unknown stresses is greater than the number of statical conditions. In this case the structure is said to be statically indeterminate, and the principle of least work must be applied. This principle asserts that the stresses under consideration have such values that the potential stress energy stored in all the members of the structure shall be a minimum. If there be n stresses under consideration and m statical conditions, the remaining $n - m$ conditions are expressed by $n - m$ equations, which are deduced by equating to zero the derivatives of the expression for the total stored energy, these being the conditions that render this energy a minimum.

As a simple example the case of a rectangular table with four legs may be considered, it being required to find the stresses in these legs due to single load placed on the table in a given position. This is a statically indeterminate problem, since rigid statics furnishes but three conditions, and the solution cannot be made if the legs are rigid. The legs are, however, really elastic and each one is shortened in supporting the load, the stress in each leg multiplied by the amount of shortening being proportional to the stored

energy in it. The amount of shortening is, moreover, proportional to the stress, if the elastic limit of the material be not exceeded. Accordingly, the stress energy in the four legs due to the given load is proportional to the sum of the squares of the four stresses, and this sum is to be made a minimum. This condition, in connection with the three statical ones, enables the four stresses due to the load to be readily determined for any given position of that load, and that these stresses actually occur is easily verified by experiment.

A close analysis of the principle of least work as applied to any framed structure will show that its applicability and its validity depend upon the fact that the longitudinal deformation of any member is proportional to the stress upon it. This law of elasticity, commonly known as Hooke's law, is closely true for the materials used in engineering structures, provided the elastic limit be not exceeded. In all cases of the design of structures it is intended that this limit shall not be surpassed, and hence the principle of least work may be used with confidence and success in computations of stresses in statically indeterminate trusses.

It is sometimes asserted that the principle of least work is a statement of a general law of nature which is obeyed not only by materials under stress but by animate beings. While it may be true that men and animals endeavor to perform their tasks in the way most economical of effort, this analogy has no bearing upon the demonstration of the principle of least work. For this demonstration rests upon the theorem of virtual velocities, the formula for the stored stress energy being the integral of that of virtual velocities. On analyzing this proof it is seen that the integration is rendered possible by the fact that the deformation of each member is assumed to be proportional to the stress upon it. This assumption indeed is the same as that of the superposition of forces, for it supposes each stress to produce its effects independently of the existence of other stresses. The theorem of virtual velocities applies to all cases of equilibrium, but its integral form does not give the principle of least work unless Hooke's law of elasticity is fulfilled. This principle, therefore, is of limited application in mechanics, and it states no general law of nature.

In the method of least squares the conditions and rules for finding the most probable values of observed quantities are derived from the principle that the sum of the squares of the residual errors

shall be a minimum. In theoretical mechanics the condition for finding the centre of mass of a system of bodies may be expressed by saying that the moment of inertia of the system shall be a minimum. In the mechanics of elastic bodies the principle of least work is analogous to these, for the conditions which must be fulfilled are those found by making the stored energy of the system a minimum. In all these cases the algebraic conditions are expressed by linear equations while the laws from which they are derived are in quadratic form, and these laws are only true when each elementary error or particle produces its effects independently of others.

Solid beams and tubes, as well as framed trusses, are subject to the principle of least work, provided the materials of which they are made conforms to Hooke's law of elasticity. For instance, the thick hollow cylinder of a gun tube is stressed under the pressure arising from the explosion of the powder, and the stress at any point varies inversely as the square of the distance between that point and the centre of the tube. It is easy to show that this law of variation is the one which makes the stored energy in the tube a minimum. So in a hollow sphere subject to interior pressure, the stresses throughout the spherical annulas vary inversely as the cubes of their distances from the centre, and this law of variation is the one which renders the stored stress energy a minimum.

The ether that fills space and transmits the force of gravitation from every particle of matter to all others has been regarded by many physicists as an elastic solid which obeys Hooke's law. If so it must be subject to the principle of least work. Any portion of matter may be supposed to exert upon the ether a compressive force, due to the fact that its molecules have displaced the ether and crowded it outwards. Then the stresses in the ether due to this displacement must be so distributed that the stored energy in the infinite sphere may be a minimum. Stating the algebraic expression for this energy due to a spherical body, it is found that its minimum value occurs when the stress at any point in the ether varies inversely as the cube of the distance of that point to the centre of the body. If gravitation be a differential effect, due to the difference of the stresses upon opposite sides of a body, the force of attraction between two spheres should vary inversely as the fourth power of the distance between their centres. From no point of view does it seem possible to deduce the actual law of

gravitation from the stresses which must exist in the ether under the supposition of perfect elasticity.

The use of the principle of least work in investigations regarding the ether of space hence leads to negative results, as far as its applicability is concerned. It indicates, however, the important conclusion that the ether is not an elastic substance in which stresses are proportional to deformations, and accordingly studies concerning it should be based upon other suppositions concerning its properties. Since the ether cannot be made the object of experiment and since all we know concerning it is from rough analogy and indirect evidence, negative conclusions are valuable. By successively discussing and rejecting one assumption after another, it is possible that in due time properties of the ether may be found which will explain not only the inertia and gravitation of matter, but also the phenomena of electricity and magnetism.

LEHIGH UNIVERSITY, SOUTH BETHLEHEM, PA.

THE "FRANKLIN PAPERS" IN THE AMERICAN PHILOSOPHICAL SOCIETY.

BY J. G. ROSENGARTEN.

(*Read April 3, 1903.*)

In the collection of this Society there are some seventy large folio volumes of "Franklin Papers." Franklin left all his papers to his grandson, William Temple Franklin, who, after a long interval, published in London and Philadelphia six volumes of Franklin's works. Of course, this represented but a small part of his papers. Those used in the preparation of Temple Franklin's edition are now the property of the United States, which has never yet printed a Calendar of them. Temple Franklin selected from his grandfather's papers those that he thought suitable for publication, and left the rest in charge of his friend, Charles Fox, to whom he bequeathed them, and Charles Fox's heirs, in turn, after a long lapse of years, presented them to the American Philosophical Society, in whose custody they have remained ever since. They have been roughly classified, and are bound in a rude and careless way. Under the present efficient Librarian, Dr. Hays, a Calendar is being made as fast as the limited means at his disposal will per

mit, and when that is completed, it is hoped that it will be printed as a useful guide to the miscellaneous matter collected here. Sparks and Hale and Ford and Parton and Fisher and others who have written about Franklin have used them, but even the most industrious student may well be appalled at the labor required to master all the contents of these bulky volumes, representing Franklin's long and many-sided activity.

He kept copies of most of his own letters and the originals addressed to him, often endorsing on them the heads of his replies. These volumes contain papers from 1735 to 1790—the first forty-four volumes letters to him; the forty-fifth, copies of his own letters; the forty-sixth, his correspondence with his wife; the forty-seventh and forty-eighth, his own letters from 1710 to 1791; the forty-ninth, his scientific and political papers; the fiftieth, his other writings—notably his *Bagatelles*, those short essays which had such a vogue and are still read; the fifty-first, poetry and verse, his own and that of others, no doubt selected by him for use in his publications; the fifty-second, the Georgia papers—he was agent for that colony; and the remaining twenty volumes, all the multifarious correspondence, other than official, mostly during his long stay in France, his various public offices at home and abroad, his enormous correspondence about appointments from men of all nationalities, who wanted to come to America, under his patronage, to fight, to settle, to teach, to introduce their inventions, for every imaginable and unimaginable purpose.

Both in England and France he kept all notices of meetings, such as those of the Royal Society and other scientific bodies of which he was a member, invitations, visiting cards, notes, business cards, etc., and at home he kept copies of wills, deeds, powers of attorney, bonds, agreements, bills, etc., and drafts, checques, bills of lading, public accounts, and even certified copies of Acts of Congress, and account books, and, in addition, Temple Franklin left eight volumes of letters to him from 1775 to 1790.

In this mass of material his biographers have found much that was of value, but there remains almost untouched the interesting correspondence of his friends in England during the years before and those of the War of Independence. There are examples of his own clever *jeux d'esprit* in the "Intended Speech for the Opening of the Parliament in 1774," in which the king himself is made to foretell the "seven or ten years' job" that his "Ministers have

put upon him to undertake the reduction of the whole Continent of North America to unconditional submission." His friend Hartley sent it to him in 1786, when the prophecy had been fully realized. Again in 1778 he received a full report of the famous dying speech of Chatham, and of that of Lord Shelburne in his defense of the American cause.

During these eventful years, his correspondents in England and in the Colonies kept him well informed both of the actions and plans of the Government and of the Opposition. Some of these may be of interest as showing how earnestly both sides were presented to him that he might use his influence to maintain peace. Priestley, who was then the Secretary of Lord Shelburne, writes from London, in February, 1776, with a due report of political and scientific information, and Lee and Wayne write to him during the campaign which was to end in Burgoyne's surrender, and thus contribute largely to the alliance with France, which owed so much to Franklin's influence not only with the French Court and French statesmen, but with the philosophers and the people.

His correspondence in Paris is a perfect picture of the time. One day he gets an invitation to attend experiments in electricity from a correspondent, Brogniart, who reports the successful treatment of sick people by electric fluid, in 1778, and soon after the Curé of Damvillers asks him for a cure for dropsy for one of his parishioners. One writer submits a plan for eliminating poverty in the United States, and Turgot asks what method Franklin advises for burning smoke and thus diminishing the consumption of wood, which was steadily getting dearer. Then comes from London an offer to disclose a method of refining common salt and using it to cure and preserve flesh and fish, for the modest fee of 2000 guineas. Genet, afterwards so well known from his troublesome career as French Minister in this country, reports progress made in August, 1778, in translation of the *Pennsylvania Gazette* accounts of battles for the French papers, and the same mail brings a letter asking Franklin's approval of mechanical and mathematical problems, and for news of Fouquet, Master Gunpowder Maker at York, Pa. Brogniart invites him to witness new experiments in electricity, and soon after he is told of a plan of six or eight Germans, men of letters and prominent position, to go to America to found a college, where the instruction can be given in Latin until the teachers have mastered English. He receives poems and eulogies

in all languages, and offers to write histories of the new Republic, provided Franklin will furnish material, maps, etc. Then comes a request to look into an invention to reunite broken bones in all cases of fracture. The Palatinate Academy of Sciences, at Mannheim, sends its works dealing with electricity, etc., and urges establishing a German Scientific Society in Philadelphia.

A man and wife, with six children and six farm laborers, desire to settle in America, and ask Franklin to get Congress to give them land near Philadelphia, enough for the support of twenty persons, their connections. Franklin notes that his reply was that land was so cheap in Pennsylvania, that there was no need to apply to Congress.

Then came an offer to establish a Swiss clock and watch factory at Boston or Philadelphia. Even Franklin's patience was tried by a request to explain the right of America to assert its independence, for on this letter he endorsed "Impertinent."

The letters are a perfect picture of Franklin's busy social life in Paris, with politics, science, literature, war, privateering, all represented in his correspondence.

There are many letters from John Paul Jones about his naval exploits, and frequent appeals for help in securing the release of prisoners captured at sea, for help to return them and other Americans in distress to their homes. Dr. Price writes from London to know if it is true that Washington is grown unpopular, and that his army deserts in great numbers, and that the suffering in America is excessive. William Strahan reminds Franklin that in 1763 he spoke of America as England's strongest ally and of France as that perfidious nation. Vaughan sends to Chaumont (who reports it to Franklin) a message of greeting for their friend who always carried spectacles on his nose and kingdoms on his shoulders.

His correspondence came from England and from all parts of the Continent and from the West Indies in an unending stream.

A very curious letter is one from Richard Penn, dated London, October 20, 1778, which I think has never been printed:

"*Dear Sir*:—Nothing but necessity could have induced me to take the liberty of begging your attention for a few moments, from those various and important affairs with which you are entrusted, and which you have executed with so much reputation to yourself and advantage to your country; at the same time I am aware that the name subscribed will not at first sight bring you much in favour

of the writer. Nevertheless I have too high an opinion of your character to imagine that any misunderstanding which might formerly have subsisted between you and any part of my family, in which I myself could have had no share, will not at all prejudice you against me and in any degree withhold you from lending me your advice and perhaps assistance upon the present occasion. I flatter myself I have some slight ground to go upon in this case, which I own I am most willing to catch at.

"I am married to your late ward, the eldest Miss Masters, and have now living with me her younger sister, still under age, and, of course, in a manner claiming your patronage, as well as their mother, the widow of your late friend. From this connection it is well known that I possess a very considerable property in the city of Philadelphia and its environs, besides two or three valuable estates of my own in the Province of Pennsylvania, a whole undivided Proprietary of New Jersey; yet with all this property, I have not been able for more than two years past to procure one shilling from that country, nor have during that time so much as received a line from my friend and agent, Mr. Tench Francis, who it is probable has at this time a handsome sum of money belonging to me in his hands. The purse I brought with me to England is nearly exhausted, tho' it has been managed with the strictest economy. I have not yet tried, nor would I willingly at present, what American security would produce in this country.

"I should think myself infinitely obliged to you if you could point out to me in what manner I could procure either from America, or in any other way, a temporary subsistence. I have not a doubt but that in time matters will turn out much to the advantage of everybody concerned and connected with that country.

"Let me entreat you to favor me with an answer to this letter under cover to my Bankers, Messrs. Barclay, Bevan & Co., No. 56 Lombard street, in doing which you will lay a lasting obligation upon one of the many who revere your character and admire your abilities.

"Give me leave to subscribe myself, Dear Sir,

"Your very sincere friend,

"RICHD. PENN."

When it is remembered that the hostility of the Penns to Franklin was so strong that Governor John Penn declined to be Patron

of the American Philosophical Society because it had chosen Franklin for its President, and that Richard Penn had been Lieutenant Governor (as Deputy for that uncle and his brother) from 1771 to 1773, it must have been difficult for Franklin not to feel that such a letter from such a man was indeed a tribute to his position, achieved solely by his own efforts.

From this mass of correspondence, I have selected some letters showing the state of public opinion in New England in 1774, and from London in 1775, including a characteristic letter from Priestley and from Charles Lee and Wayne in the field. Much more might be printed to show how well Franklin kept in touch with all that was of interest during his long and busy career. It is well that this venerable Society, so largely the result of his labors, should be made the custodian of the papers that follow almost his daily thoughts, and it is to be hoped that the preparation and publication of a Calendar showing their contents may be completed at no distant day, certainly by the two hundredth anniversary of the birth of our founder, and thus perpetuate his memory.

Franklin's legacy to the Philosophical Society was ninety-one volumes of the *History of the Royal Academy of Sciences* at Paris, thus helping that collection of publications of scientific societies that make so valuable a portion of its Library.

THE ORBIT OF THE DOUBLE STAR Σ 518.

BY ERIC DOOLITTLE.

(*Read April 3, 1903.*)

INTRODUCTION.

It is well known to astronomers that many of the stars of the sky which to the naked eye appear to be but single stars are when viewed with the telescope seen to be made up of two or more stars very close together. About twenty thousand such double stars have been measured and catalogued, and the number is continually being added to through the discoveries of the great modern telescopes. There are scarcely fifty of these, however, of which a determination of the orbit is possible.

It was in the years 1802 and 1803 that the classic memoirs of Herschel appeared, in which it was shown for the first time that

the two stars of a binary system revolve in elliptic orbits about their common center of gravity. The first method for determining the orbit of the companion star about its primary was given by Savary in 1827, who applied his method to the binary ξ Ursæ Majoris. This was thus the first double star of which an orbit was computed.

In the method of Savary, the elements of the orbit were derived from the least possible number of measures which would theoretically determine them. It was thus but very poorly adapted to secure good results, since all double star measures are liable to errors which are very large in proportion to the quantities to be determined from them. The method was improved by Encke, and other methods were subsequently devised by Sir John Herschel, Villarceau, Thiele and others; but in all of these the development was from the point of view of the pure mathematician, rather than from that of the practical astronomer.

The astronomer who essays to compute the orbit of a double star will find that he has at hand a great mass of measures, which, having been made by observers of varying experience and with instruments of all degrees of perfection, are more or less discordant. Each one of these measures consists of a determination at a given time of the distance and direction of the companion star from its primary.

If now these measures be plotted, by taking a point on the paper to represent the principal star and laying off from this point each measured distance and direction to the companion star, a series of other points will be obtained which will represent to the eye the path which the companion has pursued about its primary. Were the measures free from error, the points which indicate the position of the companion would lie accurately upon the perimeter of an ellipse; but practically they are very far from doing so, especially if the double star is very close and difficult of measurement.

The ellipse which the companion appears to describe does not represent the true orbit of the body in space, since the true orbit is viewed more or less obliquely. It is evidently the projection of the true orbit on a plane tangent to the celestial sphere at the point at which the double star is situated. While the true orbit in space is an ellipse of which the principal star occupies the focus, the apparent or projected orbit, though also necessarily an ellipse, will not have its focus at the principal star. Nevertheless, Kepler's

second Law, which states that the areas swept over by the radius-vector are proportional to the corresponding times, will evidently be true, provided that in the apparent orbit these radii-vectores are drawn from the principal star instead of from the focus.

Having plotted the series of measures as above described, the first step in the determination of a double star orbit is to draw the apparent ellipse in such a manner that it shall represent them reasonably well; the various sectorial areas are then measured with a planimeter, or otherwise, and the trial ellipse changed in shape and position until finally, after several trials, the measured positions and the law of areas are both approximately satisfied.

To fix the shape of the true orbit and its position in space, and to predict the future motion, there must next be determined the following seven elements:

(1) *The Period, P.* This can be measured directly from the apparent ellipse, since, by Kepler's Law, any sectorial area is to that of the whole ellipse as the time occupied in the description of the area is to the Period.

(2) *The Time of Periastron Passage, T.* This is the date at which the companion passes the nearer vertex of the true ellipse. It can evidently be found from the apparent ellipse by an application of Kepler's Law.

(3) *The Eccentricity, e.* This, since it is a ratio, can be obtained from the apparent ellipse.

(4) *The Inclination, i,* of the true orbit to the tangent plane.

(5) *The Longitude,* Ω, of the intersection of two planes.

(6) *The Longitude,* λ, of periastron.

The last three elements are obtained by solving a spherical triangle. The longitudes are measured from the hour circle passing through the star, from the north point in the direction of motion.

(7.) *The Semi-Major Axis, a.*

The elements of the true orbit as thus obtained enable us to predict the direction and distance of the companion for any time. The next step of the computation is to obtain the computed distance and direction at the date of each observation. A comparison of the computed with the observed positions furnishes a basis for improving the elements by the principles of Least Squares. The same process is repeated with the improved elements, until a satisfactory agreement between the computed and observed positions is obtained.

The Computation.

There are available for this determination measures on 141 nights, as shown in the following table. In the first column will be found the date of observation; in the second, the measured distance; in the third, the measured angle; in the fourth, the number of nights on which the measures were made, and in the fifth, the name of the observer.

	Date.	*ρ.*	*θ.*	*n.*	*Observer.*
		" "	°		
1	1783.13	4 to 8	326.7	1	Herschel.
2	1825.12		287 ±	1	Struve.
3	1835 to '36	"			"
4	1850.94	3.96	156.60	2	Otto Struve.
5	1851.06	3 ±	159.96	1	Dawes.
6	1851.49	3.87	155.10	2	Otto Struve.
7	1853.64	3.93	158.30	3	"
8	1854.79	4.13	155.30	1	"
9	1856.80	4.51	152.90	1	"
10	1857.82	4.40	153.00	1	"
11	1864.84	4.45	147.60	2	Winnecke.
12	1865.89	4.26	143.95	2	Otto Struve.
13	1869.10	4.46	140.40	1	"
14	1871.99	2 ±	125 ±	1	Knott.
15	1872.56	4.62	140.65	1–2	Otto Struve.
16	1873.99	4.27	133.90	1	"
17	1874.10	4.39	135.70	1	"
18	1875.14	3.80	138.10	1	"
19	1876.11	4.01	130.50	1	"
20	1877.12	2 ±	120.	1	Flammarion.
21	1877.84	3.36	127.50	3	Cincinnati.
22	1877.84	3.92	128.24	6	Burnham.
23	1877.95	3.94	126.45	4	Dembowski.
24	1878.14	4.36	125.50	1	Otto Struve.
25	1879.05	3.49	125.38	4	Burnham.
26	1879.18	3.52	125.00	2	Hall.
27	1879.75	3.29	120.00	1	Cincinnati.
28	1880.09	3.28	121.30	5	Burnham.
29	1880.95	3.16	122.06	5	"
30	1881.84	3.53	119.00	6	"
31	1882.12	3.25	118.15	2	Hall.
32	1883.00	3.07	119.20	2	Burnham.
33	1883.81	3.10	115.80	2	Hall.
34	1884.16	3.74	118.20	1	Herman Struve.
35	1886.00	3.22	112.15	2	Leavenworth.

	Date.	*ρ.*	*θ.*	*n.*	*Observer.*
		″	°		
36	1886.09	3.00	112.23	6	Hall.
37	1886.92	3.01	111.03	3	Tarrant.
38	1887.14	2.56	109.18	1–4	Schiaparelli.
39	1888.08	2.26	109.48	2	"
40	1888.12	3.04	107.68	5	Hall.
41	1888.84	2.94	106.83	3	Burnham.
42	1888.87	2.81	105.05	3	Tarrant.
43	1889.03	2.87	107.59	1–2	Schiaparelli.
44	1889.12	2.79	103.55	4	Hall.
45	1890.73	2.68	99.95	4	Burnham.
46	1890.98	1.72	99.00	3	Hough.
47	1891.01	2.62	101.49	2	Schiaparelli.
48	1891.06	2.65	98.56	5	Hall.
49	1891.78	2.48	97.38	4	Burnham.
50	1893.21	2.18	93.8	1	Comstock.
51	1895.89		83.65	0–1	Doberck.
52	1895.91	2.32	87.4	1	Collins.
53	1897.97	2.62	77.22	3	Aitken.
54	1899.11	2.39	73.6	2	"
55	1899.80	2.30	68.35	3	Doolittle.
56	1900.92	2.40	63.41	2	"
57	1903.14	2.34	55.22	4	"

NOTES—(1) Herschel placed the pair in his "Class II," which indicates that he estimated the distance as between 4″ and 8″. Otto Struve considers that at this time the distance must have been less than 4″, which seems the more probable. No use has been made of this measure in the final adjustment. (2) Excessively difficult. The angle was estimated roughly as being in the direction of the principal star, of which the position angle is 107°. The entire unreliability of this measure was first pointed out by Burnham in 1894. (3) No trace of duplicity. (14) This is merely a rough estimate. Knott used a 7⅓ inch refractor. (51) "Nearly invisible." (53) and (54) Made with the 12-inch. I have given half the theoretical weight to numbers (5), (38) and (43). (57) Was not used in the computation; these observations were made after the work was completed.

These observations were corrected for precession, and then plotted as above described, and the elements of the true orbit were derived from them. These elements were the following:

$P = 180.084$ years
$T = 1842.72$
$e = 0.129$
$i = 61.^{\circ}78$
$\Omega = 148.^{\circ}76$
$\lambda = 321.^{\circ}22$
$a = 4.''681$

Elements of the First Approximation.

For the purpose of effecting a least square solution, twelve normal places were next formed from the observations of the preceding table, as follows:

Date.	θ.	$\theta +$ Precession.	ρ.	n.
	°	°	''	
1852.48	156.89	157.13	3.95	9–8
1857.31	152.95	153.17	4.45	2
1867.95	143.54	143.70	4.42	7–6
1874.83	134.55	134.67	4.12	4
1879.03	124.89	124.99	3.56	31
1882.54	118.35	118.44	3.37	13
1887.71	108.53	108.59	2.93	31
1891.13	99.01	99.05	2.46	18
1894.06	90.60	90.62	2.25	2
1898.54	75.81	75.82	2.50	5
1899.80	68.35	68.35	2.30	3
1900.92	63.41	63.41	2.40	2

From these there resulted twelve equations between the six unknown quantities, the residuals in angle only being employed. These equations were weighted and solved for the corrections to the elements, the results being as follows:

$P = 180.039$ years.
$T = 1843.122$
$e = 0.133$
$i = 62.^{\circ}96$
$\Omega = 150.^{\circ}01$
$\lambda = 320.^{\circ}24$
$a = 4.''681$

Elements of the Second Approximation.

The residuals from these elements were not wholly satisfactory, especially between the years 1853 and 1879, when they steadily maintained the positive sign. For the purposes of a further improvement, therefore, the original observations were next grouped into the following thirty-three normal places:

Date.	*ρ.*	*θ.*	*n.*	*Observer.*
	″	°		
1850.94	3.96	156.6	2	O. S.
1851.28	3.58	156.7	3	O. S., Da.
1853.64	3.93	158.3	3	O. S.
1854.79	4.13	155.3	1	"
1856.80	4.51	152.9	1	"
1857.82	4.40	153.0	1	"
1864.84	4.45	147.6	2	Wi.,
1865.89	4.26	144.0	2	O. S.
1869.10	4.46	140.4	1	"
1871.99	2 ±	125±	1	Kn.
1872.56	4.62	140.6	1–2	O. S.
1873.99	4.27	133.9	1	"
1874.10	4.39	135.7	1	"
1875.14	3.80	138.1	1	"
1876.11	4.01	130.5	1	"
1877.86	3.80	127.5	11	D., C. O., B.
1878.14	4.36	125.5	1	O. S.
1879.09	3.50	125.3	6	B., Ha.
1880.52	3.22	121.6	10	B.
1881.84	3.53	119.0	6	B.
1882.12	3.25	118.2	2	Ha.
1883.40	3.09	117.5	4	B., Ha.
1884.16	3.74	118.2	1	H. S.
1886.30	3.04	111.9	11	L., Ha., T.
1888.51	2.95	106.7	11	Ha., B., T.
1889.12	2.79	103.6	4	Ha.
1890.84	2.27	99.6	7	B., Ho.
1891.38	2.57	98.1	9	B., Ha.
1893.21	2.18	93.8	1	Com.
1895.90	2.32	85.5	1–2	D., C.
1897.97	2 62	77.2	3	A.
1899.53	2.34	70.4	5	A., Doo.
1900.92	2.40	63.4	2	Doo.

These measures were corrected for precession, and to the resulting 33 equations there were assigned two series of weights, the first depending only on the number of nights, and the second being

arbitrarily assigned. Only the residuals in angle were employed, so that there resulted 33 equations between the six unknowns. The final values obtained from this solution led to the following elements:

P = 180.0288 ± 2.776 years.		
T = 1843.185 ± 1.051		
e = 0.13423 ± 0.0221		
i = 63°.25	± 0°.74	The Final Elements.
Ω = 150°.82	± 0°.71	
λ = 319°.54	± 0°.57	
a = 4".791		

The value of a was obtained from a series of equations of the form

$$a = \cos(\Omega - \theta c) \sec(v + \lambda) \frac{fo}{(\iota - e \cos \varepsilon)}$$

The weighted mean was taken for the value of a.

The following table shows the agreement of the observed positions with the positions computed from the final elements. These residuals are perhaps as small as can be expected with a star of this character:

Date.	*θc.*	*Prec.*	*θc—pr.*	*θo.*	*θo—θc.*	*ρc.*	*ρo.*	*ρo—ρc.*	*n.*	*Observer.*
	°	°	°	°	°	″	″ ″			
1783.23	327.33	+ 0.58	326.75	326.7	± 0.00	5.14	4 to 8		1	H.
1825.12	234.22	0.37	233.85	287 ±		1.95			1	S.[1]
1835.86	189.97	0.32	189.65			2.61			1	S.[2]
1850.94	160.15	0.25	159.90	156.60	— 3.30	3.98	3.96	″	2	O. S.
1851.06	160.20	0.25	159.75	159.96	+ 0.21	3.99	3 ±	— 0.02	1	Dawes
1851.49	159.45	0.24	159.21	155.10	— 4.11	4.01	3.87	— 0.14	2	O. S.
1853.64	156.83	0.23	156.60	158.30	+ 1.70	4.09	3.93	— 0.16	3	O. S.
1854.70	155.47	0.23	155.24	155.30	+ 0.06	4.15	4.13	— 0.02	1	O. S.
1856.80	153.10	0.21	152.89	152.90	+ 0.01	4.22	4.51	+ 0.29	1	O. S.
1857.82	151.91	0.21	151.70	153.00	+ 1.30	4.22	4.40	+ 0.18	1	O. S.
1864.84	144.06	0.18	143.88	147.60	+ 3.72	4.26	4.45	+ 0.19	2	Winnecke
1865.89	142.83	0.17	142.68	143.95	+ 1.27	4.23	4.26	+ 0.03	2	O. S.
1869.10	139.06	+ 0.15	138.91	140.40	+ 1.49	4.12	4.46	+ 0.32	1	O. S.
1871.99	135.49	0.14	135.35	125 ±	—10.35	3.99	2 ±	— 1.99	1	Knott[3]
1872.56	134.80	0.14	134.66	140.65	+ 5.99	3.97	4.62	+ .65	1–2	O. S.
1873.99	132.89	0.13	132.76	133.90	+ 1.14	3.89	4.27	+ .38	1	O. S.
1874.10	132.74	0.13	132.61	135.70	+ 3.09	3.88	4.39	+ .51	1	O. S.
1875.14	131.31	0.12	131.19	138.10	+ 6.91	3.82	3.80	— .02	1	O. S.
1876.11	129.89	0.12	129.77	130.50	+ 0.73	3.75	4.01	+ .26	1	O. S.
1877.12	128.41	0.11	128.30	120 ±	— 8 30	3.69	2 ±	— 1.69	1	Flammarion
1877.84	127.36	0.11	127.25	127.5	+ 0.2	3.64	3.36	— .28	3	C. O.
1877.84	127.36	0.11	127.25	128.24	+ 1.01	3.64	3.92	+ .28	6	B.
1877.95	127.19	0.11	127.08	126.45	— 0.63	3.63	3 94	+ .31	4	D.
1878.14	126.89	0.11	126.78	125.50	— 1.28	3.62	4.36	+ .74	1	O. S.
1879.05	125.44	0.10	125.34	125.38	+ 0.04	3.56	3.49	— .07	4	B.
1879.18	125.22	0.10	125.12	125.00	— 0.12	3.55	3.52	— .03	2	Hall
1879.75	124.25	0.10	124.15	120.00	— 4.15	3.51	3.29	— .22	1	C. O.
1880.09	123.67	0.10	123.57	121.30	— 2.27	3 48	3.28	— .20	5	B.
1880.95	122.19	0.09	122.10	122.06	— 0.04	3.42	3.16	— .26	5	B.
1881.84	120.67	0.09	120.58	119.00	— 1.58	3.35	3.53	+ .18	6	B.
1882.12	120.15	0.09	120.06	118 15	— 1.91	3.33	3.25	— .08	2	Hall
1883.00	118.48	0.08	118.40	119.20	+ 0.80	3.27	3.07	— .20	2	B.
1883.81	116.89	0.08	116.81	115.80	— 1.01	3.21	3.10	— .11	2	Hall
1884.16	116.21	0.08	116.13	118 20	+ 2.07	3.18	3.74	+ .56	1	H. Struve
1886.00	112.13	0.07	112.06	112.15	+ 0.09	3.04	3.22	+ 0.18	2	Leavenw'th
1886.09	111.94	0.07	111.87	112.23	+ 0.36	3 03	3.00	— 0.03	6	Hall
1886.92	110.10	0.07	110.03	111 03	+ 1.00	2.97	3.01	+ 0.04	3	Tarrant
1887.14	109.61	0.06	109.55	109.18	— 0.37	2.95	2.56	— 0.39	4–1	Schiaparelli
1888.08	107.43	0.06	107.37	109.48	+ 2.11	2.88	2.26	— 0.62	2	Schiaparelli
1888.12	107.32	0.06	107.26	107.68	+ 0.42	2.88	3.04	+ 0.16	5	Hall
1888.84	105.52	0.06	105.46	106 83	+ 1.37	2.82	2.94	+ 0.12	3	B.
1888.87	105.43	0.06	105.39	105.05	— 0.34	2.82	2.81	— 0.01	3	Tarrant
1889.03	105.05	0.05	105.00	107.59	+ 2.59	2.81	2.87	+ 0.06	2–1	Schiaparelli
1889.12	104.82	0.05	104.77	103.55	— 1.22	2.81	2.79	— 0.02	4	Hall
1890.73	100.39	0.05	100.34	99.95	— 1.39	2.70	2.68	— 0.02	4	B.
1890.98	99.70	0.05	99.65	99.00	— 0.65	2.68	1.72	— 0.96	3	Hough
1891.01	99.62	0.04	99.58	101.40	+ 1.91	2.68	2.62	— 0.06	2	Schiaparelli
1891.06	99.49	0.04	99.45	98 56	— 0.89	2.67	2.65	— 0.02	5	Hall
1891.78	97.40	0.04	99.36	97.38	— 1.98	2 63	2.48	— 0.05	4	B.
1893.21	93.10	0.04	93.06	93.8	+ 0.70	2.55	2.18	— 0.37	1	Comstock
1895.89	84.17	0.02	84.15	83.65	— 0.50	2.43			1	Doberck[4]
1895.91	84.14	0.02	84.12	87.4	+ 3.30	2.43	2.32	— 0.11	1	Collins
1897.97	76.73	0.01	76.72	77.22	+ 0.50	2.36	2.62	+ 0.26	3	Aitkin[5]
1899.11	72.49	0.00	72.49	73.6	+ 1.10	2.33	2.39	+ 0.06	2	Aitkin
1899.80	69.50	0.00	69.50	68.35	— 1.15	2.32	2.30	— 0.02	3	Doolittle
1900.92	65.61	0.00	65.61	63.41	— 2.20	2.31	2.40	+ 0.09	2	Doolittle
1903.14	57.19	D .02	57.21	55.22	— 1.99	2.34	2.46	+ 0.12	4	Doolittle

[1] "A very vague estimate" (O. S.).
[2] "No trace of duplicity."
[3] This is a rough estimate merely; Knott used a 7½-inch.
[4] "Nearly invisible."
[5] 12-inch.

There have been two determinations made of the parallax of this star; the first determination was by the heliometer by Gill in 1882, and the second was by micrometric measures by Hall in 1884. The results were:

Gill,	0″.16	19.6 light years.
Hall,	0″.22	14.6 light years.

If we assume the mean of these, or 0″.19, as the most probable value, the dimensions of the orbit and the combined mass of the two components can readily be determined. We find that the sum of the masses of the two components is nine-tenths the mass of our sun, and that the semi-major axis of the true orbit is 23.5 times the distance from the earth to the sun. The orbit is thus larger than the orbit of Uranus, but inferior to that of Neptune.

UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA.

SOME ABORIGINAL LANGUAGES OF QUEENSLAND AND VICTORIA.

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(*Read October 3, 1902.*)

Last year I contributed to this Society a short description of the Gundungurra, one of the native tongues of New South Wales. In the following pages it is proposed to furnish the outlines of the grammatical structure of some aboriginal languages spoken by the native tribes of Queensland and Victoria.

The method of spelling adopted is that recommended by the Royal Geographical Society of London, with the following qualifications:

As far as possible vowels are unmarked, but in some instances the long sound of a, e, and u are indicated thus, ā, ē, ū. In a few cases, to avoid ambiguity of pronunciation, the short sound of u is thus represented, ŭ.

G is hard in all cases. R has a rough, trilled sound, as in "hurrah!" W always commences a syllable or word. Y at the beginning of a word or syllable has its ordinary consonant value.

The sound of the Spanish ñ often occurs; at the beginning of a

word or syllable I have given it as *ny*, but when terminating a word the Spanish letter is employed.

Ng at the beginning of a word or syllable has a peculiar nasal sound. At the end of a syllable it has substantially the sound of ng in "sing."

Dh is pronounced nearly as th in "that," with a slight sound of d preceding it. Nh has likewise nearly the sound of th in "that," but with an initial sound of the n. A final h is guttural, resembling ch in the German word "bach."

T is interchangeable with d, p with b, and g with k, in most words where these letters are used.

Ty and dy at the commencement of a word or syllable has nearly the sound of j. At the end of a word ty or dy is pronounced nearly as tch in "batch" or "ditch," omitting the final hissing sound.

All the details supplied in this article were taken down by myself from the lips of the natives speaking the languages herein dealt with—a tedious and laborious task.

The Murawarri Language.

In a communication to this Society in 1898 I described the social divisions and laws of intermarriage prevailing in the Murawarri tribe, together with a comprehensive list of totems, and will now proceed to exhibit the structure of their language. This tribe occupies an extensive region on the southern frontier of Queensland, between the Warrego and Culgoa rivers, reaching also some distance into New South Wales. Languages similar in grammar to the Murawarri, although differing somewhat in vocabulary, extend northerly into Queensland for hundreds of miles.

NOUNS.

Number.—Nouns have three numbers, the singular, dual and plural. Gula, a kangaroo. Gulabural, a pair of kangaroos. Guladhunna, several kangaroos. The suffix dhunna is frequently shortened to dhu, in rapid conversation.

Gender.—Mēn, a man. Mugiñ, a woman. Guthera, a small boy. Gutheragamba, a small girl. The sex of animals is distinguished by using, after the name of the creature, the words dhungur, male, and guni, female, and these words take inflexion for number and case.

Case.—The principal cases are the nominative, causative (or nominative-agent), genitive, accusative, instrumental, dative and ablative.

The nominative merely names the animal or thing, as, nguruñ, emu; dhagguñ, padamelon; wirri, bandicoot; wagan, crow; mulli, boomerang; kinni, yamstick; gūndal, dog; gugai, opossum; ngura, a camp; wungga, a bird's nest.

Causative: Guladyu ngunna wirrunga, a kangaroo me scratched.

Instrumental: Mēndyu wagan mullinyu bundhara, a man a crow with a boomerang hit.

Genitive: Mugingu kinni, a woman's yamstick. Wagangu wungga, a crow's nest.

Dative: Dhan yanna nguranggu, come to the camp.

Ablative: Dhirri yanna ngurango, go away from the camp.

Accusative: This is the same as the nominative.

ADJECTIVES.

Adjectives are placed after the nouns they qualify, and are similarly inflected for number and case.

Nominative: Gundal kittyu, a dog small; gundalbural kittyubural, a couple of small dogs; gundaldhu kittyudhunna, several small dogs.

Causative: Mugindyu thurdadyu guthera bundhara, a woman large a child beat.

Genitive: Mēngu thurdagu mulli, the large man's boomerang.

Adjectives are compared by using such phrases as, thurda nhu, kittyu nūngga, large this, small that. Superiority is implied by saying, thurdaburra, very large.

PRONOUNS.

Pronouns are inflected for number and person, and comprise the nominative, possessive and objective cases, some examples of which are given in the following table. There are forms in the first person of the dual and plural to express the inclusion or exclusion of the party addressed:

Singular.

	Nominative.	*Possessive.*	*Objective.*
1st Person.....	Ngadhu	Ngundi	Ngunna
2d "	Ngindu	Ingga	Bunga
3d "	Yallunggo	Ngumboga	Bunha

Dual.

1st Person	.....Ngulli	Ngulliga	Ngullinya
	.....Ngulliñūmba	Ngulligilunna	Ngullinyanumba
2d "	.....Nula	Nulaga	Nulanna
3d "	.....Yallabural	Bulaga	Burannha

Plural.

1st Person	.....Nginna	Nginnaga	Ngurranna
	.....Nginnadyula	Nginnagadyula	Ngurranadyula
2d "	.....Nura	Nuraga	Nuranna
3d "	.....Yalladhunna	Dhurraga	Dhurrana

There are forms of the pronouns signifying "to me," "from me," "with me," and so on, as in the following few illustrations:

Dhangandhera dhiga, he brought it to me.

Dhirrithunggia dhigamil, he ran away from me.

Ngunnhura niambu, with me rests he.

Interrogatives: Ngannga, who? Nganngabural, who (dual)? Nganngadhunna, who (plural)? Ngangagu, whom belonging to? Minya, what? Minyanggu, what for?

Demonstratives: This, nhu; that, nhurana. These demonstratives are very numerous, according as the object referred to is in front of, behind, near, or far from the speaker. Many of them take inflexion for number and person.

VERBS.

Verbs have the singular, dual and plural numbers, the usual persons and tenses, and three principal moods—indicative, imperative and conditional. There is a distinctive form of the verb for each tense—present, past and future; but number and person are shown by short pronominal suffixes to the stem of the verb. These rules will be readily understood on perusing the following conjugation of the verb, bundhera, to beat:

Indicative Mood—Present Tense.

Singular....	1st Person.....	I beat	Bundhiyu
	2d "	Thou beatest	Bundhindu
	3d "	He beats	Bundhibu
Dual.....	1st Person.....	We, incl., beat	Bundhili
		We, excl., beat	Bundhilinūmba
	2d "	You beat	Bundhinula
	3d "	They beat	Bundhibula

Plural.....	1st Person.....	We, incl., beat	Bundhina
		We, excl., beat	Bundhinadyula
	2d "	You beat	Bundhinura
	3d "	They beat	Bundhira

Past Tense.

Singular....	1st Person.....	I beat	Bundharanyu
	2d "	Thou beatest	Bundharandu
	3d "	He beat	Bundharabu

Future Tense.

Singular....	1st Person.....	I will beat	Būnggunyu
	2d "	Thou wilt beat	Būnggundu
	3d "	He will beat	Būnggubu

It is thought unnecessary to give the dual and plural numbers of the past and future tenses.

Imperative Mood.

Positive.....Beat	Būngga
Negative.....Beat not	Būngga wulla

Conditional Mood.

I may beat	Wullawurri būnggunyu

Reflexive.

I am beating myself	Bundherriyu
I was beating myself	Bundherriaiyu
I will beat myself	Bundherriguyu

The inflexion continues through all the persons.

Reciprocal.

Dual.....	We, incl., are beating each other	Bumbullāli
	We, incl., will beat each other	Bumbullaguli
Plural.....	We, incl., are beating each other	Bumbullana
	We, incl., will beat each other	Bumbullaguna

The second and third persons of the dual and plural also take reciprocal inflexion.

The following examples show the native way of expressing the English verb "to be":

Present.....I am well	Murriñ indiyu (well am I)
Past .....I was well	Murriñ indayu (well was I)
Future .....I will be well	Murriñ inguyu (well will be I)

ADVERBS.

Yes, kaila. No, wulla. Here, nunggo. There, ngurra. Now, kunyegaila. By and bye, kunye. Yesterday, gūnda. Tomorrow, būrda. A few days ago, buggera dhurungga. Long ago, muttyagaila. Perhaps, wullawurri. Slowly, mūn-gi. Rapidly, kurdugurdu. Where, dhirrungga? Where (if two), dhirrambula? Where (plural), dhirradhunna? How many, minyungurra?

PREPOSITIONS.

In front, kurbu. Behind, billungga. In the rear, durungga. Inside, mugungga. Outside, bullungga. Beside me, gurgungga dhiga. Between, dhunnūngga. Down, burrungga. Up, gūnda. Over or across (referring to a river, hill, etc.), gurrundha. This side of, nhubarañ. The other side, beyond, gowurrigurrundha. Through, gaimyu. Towards, dhai. Away from, dhirra.

Several prepositions take inflexion for number and person: Behind me, billunggadhiga. Behind thee, billunggabunga. Behind him, billunggabuga. Behind us, billunggangurriga, and so on.

CONJUNCTIONS AND INTERJECTIONS.

It is not thought necessary to supply illustrations of these parts of speech.

NUMERALS.

One, yaman. Two, kubbo. Several, murabirri.

THE WAMBA WAMBA LANGUAGE.

This language is spoken among the remnants of the native tribes about Swan Hill on the Murray river, and extending southerly into the State of Victoria beyond Lalbert and Tyrrell creeks, the lower Avoca river, etc. The people are divided into two phratries, Gamaty and Gurgity, the men of one phratry marrying the women of the other. For lists of totems attached to these phratries, the reader is referred to a paper I contributed in 1898 to the Anthropological Society at Washington.[1]

[1] "The Victorian Aborigines: their Initiation Ceremonies and Divisional Systems," *American Anthropologist*, Vol. xi, pp. 333, 334. Map of Victoria, Plate V.

All the languages spoken in the eastern portion of Victoria are identical in grammatical structure with the Gundungurra language reported by me to this Society last year, although their vocabularies are altogether different. Westward of the 145th meridian of longitude all the Victorian languages have the same structure as the Wamba Wamba, with the exception of a strip of country on the lower Murray river.

NOUNS.

Number.—Karrange, a kangaroo. Karrange bullang, two kangaroos. Karrange girtāwal, several kangaroos.

Gender.—Wurtūnge, a man. Laiur, a woman. Banggo, a boy. Bannulaiur, a girl. Bupu, a child of either sex. The sex of animals is indicated by using the word mamo for males, and baba for females; thus, willunge mamo, a male opossum; willunge baba, a female opossum.

Case.—The nominative: Wanne, a boomerang. Kenninge, a yamstick. Wirrangin, a dog. Lūrnge, a camp.

The Causative: Wurtulu karange dhakkin, a man hit a kangaroo. Laiuru bupu dhakkin, a woman beat a child.

Possessive: Wurtua wanne, a man's boomerang. Every object over which ownership can be exercised is subject to inflection for number and person, thus:

Singular	1st Person.....	My boomerang	Wannai
	2d "	Thy boomerang	Wannin
	3d "	His boomerang	Wannu

This declension extends to all the persons and numbers, in each of which one example will be sufficient:

Dual.....Our, inclusive, boomerang	Wannul
Trial.....Our, inclusive, boomerang	Wannangurkullik
Plural.....Our, inclusive, boomerang	Wannungur

Dative: Lūrndal, to the camp.

Ablative: Lūrnung, from the camp.

ADJECTIVES.

Adjectives follow the noun qualified, as kūrwinge kurong-untu, an emu large. Kurwinge bannutu, an emu small. They are inflected for number and case like the nouns, and comparison is effected as in the Murawarri

PRONOUNS.

Pronouns have four numbers, singular, dual, trial, and plural. There are double forms of the first person to include or exclude the person spoken to. The following table shows the nominative and possessive pronouns:

Singular.

1st Person	I	Yetti	Mine	Yenneu
2d "	Thou	Nginma	Thine	Nginneu
3d "	He	Kinyi or Kalu	His	Kikinga

Dual.

1st Person	We, incl.,	Ngulli	Ours, incl.,	Ngullidha
	We, excl.,	Ngullu	Ours, excl.,	Ngulludhu
2d "	You	Nyula	Yours	Nyuladhu
3d "	They	Kalubulang	Theirs	Kinyebuladhu

Trial.

1st Person	We, incl.,	Yangurkullik	Ours, incl.,	Yanguradhukullik
	We, excl.,	Yandakkullik	Ours, excl.,	Yandhadhukullik
2d "	You	Ngutakullik	Yours	Ngutadhukullik
3d "	They	Kaludhanakullik	Theirs	Dhanadhukullik

Plural.

1st Person	We, incl.,	Yangur	Ours, incl.,	Yanguradhu
	We, excl.,	Vandhank	Ours, excl.,	Yandhadhu
2d "	You	Nguta	Yours	Ngutadhu
3d "	They	Kaludhana	Theirs	Dhanadhu

There are objective forms of the pronouns, signifying me, with me, towards me, from me, and so on. Interrogative and demonstrative pronouns are also various and precise.

VERBS.

Verbs have the same numbers and persons as the pronouns, three tenses and three principal moods; as exhibited in the following conjugation of the verb "to sit":

Indicative Mood—Present Tense.

Singular	1st Person	I sit	Ngangan
	2d "	Thou sittest	Ngangar
	3d "	He sits	Nganga

Dual.....	1st Person...	We, incl., sit	Ngangangul
		We, exclu., sit	Ngangangullu
	2d "	You sit	Nganganyulu
	3d "	They sit	Ngangabulang
Trial.....	1st Person...	We, incl., sit	Ngangangurkullik
		We, excl., sit	Ngangandhankullik
	2d "	You sit	Ngangangutakullik
	3d "	They sit	Ngangandhanakullik
Plural.....	1st Person...	We, incl., sit	Ngangangur
		We, excl., sit	Ngangandhak
	2d "	You sit	Nganganguta
	3d "	They sit	Ngangandhana

Past Tense.

Singular	1st Person.....	I sat	Nganginan
	2d "	Thou sattest	Ngangінar
	3d "	He sat	Ngangin

Future Tense.

Singular	1st Person.....	I will sit	Nganginyan
	2d "	Thou wilt sit	Ngangiпyar
	3d "	He will sit	Ngangiñ

The remaining moods are omitted, being similar in constitution to those of the Murawarri.

This is the first occasion on which the *trial*, or *triple*, number has been reported in the verbs of any Australian language. Mr. J. J. Carey, from the MS. of the late Mr. F. Tuckfield,[1] published a list of pronouns in what he calls the Woddowro language, but which I spell Wuddyāwurru, in which he shows an incomplete set of trial pronouns. He did not, however, observe the double form in the first person of the dual, trial and plural, which is now communicated by me in the languages of Victoria for the first time.[2]

Among the native tribes on the upper Campaspe, Lodden and Avoca rivers, instead of *kullik* being the sign of the trial, the word *baiap* is employed, as, Ngurnabuingunyinbaiap, we three sit.

[1] *Rep. Aust. Assoc. Adv. Sci.*, Vol. vii, p. 842 and p. 853.

[2] I have, however, previously discovered and reported the existence of two forms of the first person of the dual and plural in the nouns, pronouns, verbs, adverbs and prepositions of the Gundungurra, one of the native languages of New South Wales: PROC. AMER. PHILOS. SOC., Vol. xl, pp. 140–148.

Tyilbuingunyinbaiap, we three beat. It will be apparent that the words *baiap* or *kullik* are merely superadded to the suffix of the plural.

In the Motu, one of the languages of New Guinea, Rev. W. G. Lawes reports that the dual and trial of pronouns are formed by additions to the plural.[1]

If a line be assumed to be drawn on the map of Victoria from Melbourne to Echuca, then the whole of that portion of Victoria situated on the eastern side of that line has no trial number in its speech, but in all the languages to the west of that line the trial number obtains.

ADVERBS AND PREPOSITIONS.

In principle these resemble the same parts of speech in the Murawarri and Gundungurra, and some of them take similar inflexion for number and person.

Interjections and exclamations are not numerous and have been omitted.

NUMERALS.

One, yuwaia. Two, bulle. Several, girtāwal.

A NEW FRESH-WATER MOLLUSCAN FAUNULE FROM THE CRETACEOUS OF MONTANA.

(Plate IV)

BY TIMOTHY W. STANTON.

(*Read April 3, 1903.*)

An interesting collection of fresh-water invertebrate fossils, collected in Montana by a recent expedition from the Geological Department of Princeton University, has been placed in my hands for study through the courtesy of Prof. W. B. Scott and Dr. A. E. Ortmann. Although the collection contains only half a dozen species, it is of more than usual interest on account of the excellent preservation of the fossils and the fact that they probably come from either a new horizon for fresh-water mollusks, or at least a new

[1] *Motu Grammar* (Sydney, 1896), p. 9.

basin, as is indicated by their apparent distinctness from all described species.

According to the labels the fossils all come from one locality on Wettacombe's ranche near Harlowton, on the Musselshell River, Montana, where they were collected by Dr. M. S. Farr and Mr. A. Silberling. The interesting Mesozoic and Tertiary section of this region lying in Sweetgrass county, east of the Crazy Mountains and south of the Big Snowy Mountains, has been somewhat fully described by Mr. Earl Douglass,[1] who states that the Fort Union, the Laramie and the familiar Meek and Hayden section of the marine Upper Cretaceous are well represented. Beneath the Fort Benton formation is a thick series—"many hundreds of feet"—of sandstones and shales, of which the upper part is supposed to represent the Dakota and the lower part—"largely red in color"—yielded bones of large Dinosaurs, fossil wood and these invertebrates. Douglass refers this part of the section with doubt to the Jurassic, though he states that the vertebrate remains have not been studied. I have not been informed as to whether the mollusks and vertebrates occur in exactly the same bed. Apparently the exposure does not extend to beds as low as the marine Jurassic, which is known to occur in this general region, and which belongs to the upper part of the Jurassic system.

It is evident from the above statement that the fresh-water horizon in question lies somewhere between the marine Upper Jurassic and the Fort Benton, which may be correlated with the Turonian of Europe. This interval, covering the lower part of the Upper Cretaceous, all of the Lower Cretaceous and possibly the latest Jurassic, is not represented by marine strata in the northern interior region. Instead there is a number of non-marine formations in various parts of the region, whose relationships to each other are obscure, their principal point of resemblance in most cases being an apparently similar stratigraphic position.

Since in other parts of the continent this interval includes the equivalent of the Comanche series, consisting of several thousand feet of marine sediments and containing a number of distinct faunas, it is evident that there is room for many distinct horizons of fresh-water beds, and it would not be surprising if those of different ages were in some cases developed in different parts of the

[1] *Science*, n. s., Vol. XV, pp. 31 and 272, January 3 and February 14, 1902; *Proc. Amer. Philos. Soc.*, Vol. XLI, pp. 207–224, 1902.

large area, so that their exact stratigraphic relations with each other are not observable. It will therefore be necessary to consider the different formations and horizons that have been recognized, in order to make an approximate determination of the age of the fossils now under consideration.

In southern Wyoming the marine Jurassic is immediately overlain by the Como beds (formerly called Atlantosaurus beds), containing a large reptilian fauna and a considerable number of Unios and other fresh-water shells. Similar beds that are correlated with them by means of the fossils occur in the Black Hills, along the Front Range in Colorado and elsewhere in the Rocky Mountain region. These beds have usually been referred to the Jurassic, though recently several paleontologists have referred them to the Lower Cretaceous. The mollusca are of modern types, mostly belonging to genera that are still represented by living species, but the specific forms are quite distinct from all those found fossil in later beds. Of all the species that have been assigned to the Como horizon only one (*Viviparus gilli* M. and H.) is comparable with a form in this Montana collection, and that one is from a locality near the head of Wind River, Wyoming, where it was associated with *Liaplacodes veternus* M. and H. and *Neritina nebrascensis* M. and H. As none of these three species has been found elsewhere,[1] the age of the bed from which they came is doubtful, and may well be later than the Como.

Two non-marine formations of this general region, the Cascade and the Lakota,[2] have been referred to the Lower Cretaceous. The Cascade formation, which occur in the neighborhood of Great Falls, Montana, is coal-bearing and has been correlated by means of the fossil plants with the Kootanie of the neighboring Rocky Mountain region in Canada, and with the lower Potomac of the Atlantic border. Its geographic position and the apparently similar stratigraphic relations favor the supposition that the fresh-water beds near Harlowton may belong to the Cascade (Kootanie) formation, but unfortunately the former have yielded no plants except fossil wood, and the fauna of the latter is practically unknown. Obscure imprints of Unio have been reported from the Cascade, but nothing sufficiently definite for description. A few undescribed

[1] Logan inadvertently describes *Planorbis veternus* as *Liaplacodes* from the Freeze-out Hills of Wyoming, in *Kansas Univ. Quart.*, Vol. IX, p. 132, 1900.

[2] Named by Weed in the Fort Benton Folio, *Geol. Atlas of the United States.*

fresh-water gastropods have been collected from beds immediately overlying the Cascade and referred by Mr. Weed to the Dakota, and these are of types different from any in the Harlowton collection. That is, they are not specifically comparable.

The Lakota formation is found in the Black Hills region, where it is said to overlie beds correlated with the Como beds, and to underlie the Dakota. It is characterized by a flora, by means of which its Lower Cretaceous age has been determined, and it has been tentatively correlated with a part of the Potomac and by inference also with the Kootanie and a part of the Glen Rose beds. It has yielded no animal remains, and therefore needs no further mention in this connection.

Beds that have been referred to or correlated with the Dakota have a wider distribution than any of the other formations above mentioned. The original area is in northeastern Nebraska on the Missouri River, from which the formation has been satisfactorily traced and identified through Nebraska and Kansas, where it covers considerable areas on the Great Plains. It consists of several hundred feet of coarse sandstone with some shales, passing up into the Fort Benton shales with evident continuity of sedimentation. Paleontologically it is chiefly characterized by its large flora. It has yielded a very few marine and brackish water mollusca, but although it was evidently deposited at or near sea level it seems to have been largely non-marine in character, since a number of localities in it have yielded fresh-water mollusca. The abundant land flora also indicates non-marine conditions. The fauna[1] includes species of Unio, Margaritana, Corbula, Goniobasis, Viviparus and Pyrgulifera, none of which is specifically closely related to the species described in this paper. The Dakota has also been well identified in the Black Hills region and along the eastern base of the Rocky Mountains in Colorado. It has been mapped in many areas farther west in Wyoming, Montana, Utah, and elsewhere, but the correlation is certainly erroneous in some of these areas and must be considered doubtful in many of them, because the identifications have been based entirely on very general comparisons of the lithology and stratigraphy. It has been the general custom to refer to the Dakota any formation consisting in part of conglomerates and sandstones and underlying the

[1] See C. A. White, "Notes on the Invertebrate Fauna of the Dakota Formation," *Proc. U. S. Nat. Mus.*, Vol. XVII, pp. 131–138, 1894.

marine Cretaceous. That the formations thus assigned in many cases include the equivalent of the true Dakota is very probable, but that they may also include other horizons, laid down in the long interval between the Jurassic and the Upper Cretaceous, is equally probable. In the Yellowstone Park and adjacent areas the supposed Dakota includes bands of impure limestone filled with fresh-water shells not found elsewhere. Among them is a Unio represented by rare casts and fragments, but the most of them are simple gastropods, the most common of which I have described as *Goniobasis ? pealei, G.? increbescens* and *Amnicola ? cretacea*.[1] The beds referred to the Dakota near Great Falls, Montana, already mentioned, contain another assemblage of three or four species of fresh-water mollusca not known elsewhere. None of these supposed Dakota beds in the region just mentioned yielded the characteristic Dakota flora.

The Bear River formation of western Wyoming is the last one to be considered in this connection. It consists of a great thickness (as much as 4000 feet in some sections) of conglomerates, sandstones and shales, having a large and peculiar fresh-water fauna. Its principal known area extends from the neighborhood of Evanston, on the Union Pacific Railroad, northward near the western boundary of Wyoming for more than a hundred miles. Originally it was assigned to the Tertiary, afterward to the Laramie, or uppermost Cretaceous. It is now known to lie between the Fort Benton and the marine Jurassic,[2] but just how much or what part of this interval it represents is not positively known. Some of the conglomerates associated with the fossiliferous beds have probably been mapped as Dakota by the early surveys. The occurrence of a few undetermined dicotyledonous plants of modern type in the formation favor its assignment to the Upper Cretaceous. The fauna is not closely related to any other known on this continent, as all the species are restricted to it, and at least two of the gastropod types are so peculiar that they have been described as new genera. The entire fauna has been reviewed and figured by Dr. C. A. White,[3] who has made detailed comparisons with other non-marine faunas. One of the most striking of the common fossils of the fauna is *Pyrgulifera*

[1] *Monog. U. S. Geol. Surv.*, Vol. XXXII, Pt. 2, pp. 632, 633, 1899.

[2] See Stanton: "The Stratigraphic Position of the Bear River Formation," *Am. Jour. Sci.*, 3d ser., Vol. XLIII, pp. 98–115, 1892.

[3] *Bull. U. S. Geol. Surv.*, No. 128.

humerosa Meek, and the genus to which it belongs was not known to occur in America outside of the Bear River formation until a few years ago, when a species apparently referable to it was described from the Dakota of Nebraska, and another undescribed species is now known from the same formation in Kansas. This fact is an additional indication that the Bear River and Dakota are of nearly the same age.

It is worthy of note that the Bear River fauna includes an Ostrea, which proves that the formation was deposited at or near sea level, and that the waters occasionally became brackish, at least locally. The geographic distribution of the older marine formations makes this occurrence of Ostrea still another reason for considering the Bear River an Upper Cretaceous formation.

The six species of invertebrates from near Harlowton will be described on succeeding pages under the following names:

Unio farri.
Unio douglassi.
Campeloma harlowtonensis.
Viviparus montanaensis.
Goniobasis? ortmanni.
Goniobasis? silberlingi.

These are all new specific names, and it will be necessary to depend on the known range of the species that appear to be most closely related in attempting to determine the age of the beds from which they came.

Two of the species, *Unio douglassi* and *Campeloma harlowtonensis*, have their nearest relatives in the Bear River formation. *Unio douglassi* is of the same general type as *U. vetustus* Meek and has very similar beak sculpture, though it differs considerably in outline and proportions. *Campeloma harlowtonensis* resembles *C. macrospira* Meek so closely that it is difficult to separate them.

Viviparus montanaensis, as has already been stated, is closely related to *V. gilli* M and H., which has been doubtfully referred to the Jurassic.

The other species of Unio is of modern type, but apparently not very closely related to any known fossil species, while the two forms that are here referred to Goniobasis have a very modern aspect, suggesting Upper Cretaceous rather than older types.

Although the evidence is not fully convincing, the indications are that this fresh-water horizon near Harlowton is not far from the hori-

zon of the Bear River formation—possibly contemporaneous with a part of it—and that it is certainly not older than Lower Cretaceous, and more probably should be assigned to about the base of the Upper Cretaceous.

The facts thus briefly related should call renewed attention to the important and apparently complex history recorded in the non-marine formations of the late Jurassic and early Cretaceous of the Northwest—a history that is as yet far from being fully understood, although it is evident that the deposits contain the record of a great many facts that await the detailed investigation of the region for their interpretation.

Description of Species.

Unio farri n. sp. Pl. IV, Figs. 1, 2.

Shell small, short and relatively convex; beaks somewhat prominent and inflated, situated about one-third the length of the shell from the anterior end, not sculptured nor eroded; dorsal margin nearly straight; ventral margin moderately convex; anterior end regularly rounded; posterior end obliquely subtruncate; umbonal ridges rather prominent, rounded, extending to the postero-ventral angle; surface marked only by moderately prominent, irregularly arranged lines of growth.

The type specimen measures 37 mm. in length, 22 mm. in height, and 16 mm. in convexity of both valves. The largest specimen of the eight in the collection is 45 mm. in length. Three of the specimens are relatively somewhat more compressed and longer and have the posterior end more obliquely truncated. These differences are believed to be sexual rather than specific and are not greater differences than are seen in some living species of Unio. One of these compressed specimens (represented by Fig. 2) measures 40 mm. in length, 22 mm. in height and 13 mm. in convexity.

This species is suggestive of the *parvus* group of living Unios, but is not sufficiently closely related to any fossil species from our Western formation to require detailed comparison.

Locality.—Wettacombe's ranche near Musselshell River, in the vicinity of Harlowton, Montana.

Horizon.—Upper part of Lower Cretaceous or base of Upper Cretaceous.

UNIO DOUGLASSI n. sp. Pl. IV, Figs. 3, 4.

Shell below medium size, elongate, rather slender and moderately convex; beaks small, inconspicuous, situated about one-fourth the length of the shell from the anterior end; dorsal margin nearly straight; ventral margin very gently convex; anterior end regularly rounded; posterior end broadly rounded below and very obliquely subtruncate above, so that its termination is acutely subangular; umbonal region strongly sculptured over an area about 17 mm. long and 7 mm. high, with prominent concentric ribs, crossed on the posterior portion by two sharply elevated, linear, radiating ribs, one of which is on the umbonal ridge and the other midway between it and the postero-dorsal margin. The concentric ribs change their direction abruptly and have their continuity more or less broken in crossing the radiating ribs, especially the upper one. The rest of the shell shows only moderately distinct growth-lines, except on the postero-dorsal area above the umbonal ridge, which shows numerous faint, slightly curved, irregular radiating lines.

An average specimen measures 56 mm. in length, 24 mm. in height and 15 mm. in convexity (both valves), the greatest height and convexity being about midlength of the shell. A few specimens appear to be relatively somewhat more compressed and higher, but this is due, in part at least, to accidental distortion. The species is represented by about forty specimens.

This species closely resembles *Unio vetustus* Meek from the Bear River formation in all the details of sculpture, but it differs from that species in its smaller size and much more slender form.

Locality.—Wettacombe's ranche near Musselshell River, in the vicinity of Harlowton, Montana.

Horizon.—Upper part of Lower Cretaceous or base of Upper Cretaceous.

VIVIPARUS MONTANAENSIS n. sp. Pl. IV, Fig. 5.

Shell small, rather stout, subovate, consisting of about five rapidly increasing whorls; volutions rounded below and obtusely subangular and flattened above, so that they are more or less distinctly shouldered; last volution slightly expanded at the aperture, which is broadly ovate; outer lip simple, nearly straight in profile outline; inner lip moderately thick, closely appressed to the shell above, very slightly elevated and reflexed below; surface bearing only very fine lines of growth.

The figured type, which is of about the average adult size, gives the following measurements: Height, 12 mm.; greatest breadth, 10 mm.; height of aperture, 7 mm.; breadth of same, 5 mm. The collection contains about two hundred specimens, which show little variation except in size. Part of the specimens, supposed to be immature, are considerably smaller than the type.

This species is very similar in general appearance to *Viviparus gilli* Meek and Hayden, which was described[1] from beds provisionally referred to the Jurassic at the head of Wind River, Wyoming, but it differs from the Wyoming form in being slightly smaller, and in having more distinctly shouldered whorls, a more oblique aperture, and with the inner lip more closely appressed to the shell and not so prominent.

Locality.—Wettacombe's ranch near Musselshell River, in the vicinity of Harlowton, Montana.

Horizon.—Upper part of Lower Cretaceous or base of Upper Cretaceous.

CAMPELOMA HARLOWTONENSIS n. sp. Pl. IV, Figs, 11, 12.

Shell large, elongate subovate, consisting of about six elevated convex whorls, separated by a linear impressed suture; aperture large, ovate; inner lip moderately thick, forming a rather heavy callus on the shell above and slightly reflexed below, so as to partly cover the small umbilical depression or chink; surface marked only by fine, slightly sigmoid lines of growth.

The type, which is the largest specimen in the collection, measures 63 mm. in height (with apex restored) and 38 mm. in greatest breadth; height of aperture 34 mm. and breadth of same 23 mm. The other figured specimen is 57 mm. in height (with apex restored), 38 mm. in breadth, and the corresponding dimensions of the aperture are 29 mm. and 22 mm. respectively.

This second specimen shows other differences in the aperture besides its relatively greater breadth, the inner lip being thicker and not so closely applied to the preceding whorl above and having a larger umbilical depression uncovered below. These variations are probably all accidental, as there is distinct evidence of injury to the shell during the life of the animal, shown by a repaired break nearly parallel to the outer lip and a few millimeters from it.

[1] *Palaeont. of the Upper Missouri*, p. 115, Pl. V, Fig. 3, *a*, *b*, Washington, 1865. Figured also by White in Bull. No. 29 and in *Third Ann. Rept. U. S. Geol. Surv.*

There are seventeen other less perfect specimens in the collection, all of which agree fairly well with the type so far as their characteristics are preserved.

This species is very closely related to *Campeloma macrospira* Meek,[1] and may prove to be not more than a variety of that species from the Bear River formation in western Wyoming. Comparison of *C. harlowtonensis* with the type and with a large suite of specimens from the same horizon in Wyoming show that Meek's species averages considerably smaller, and that it is somewhat more slender, with the sutures slightly more oblique and the last whorl relatively larger. The last-named peculiarities cause a greater difference in the aspect and proportions of the shells than would be indicated by measurements. There are also differences in the form of the inner lip. There are, however, associated with the typical form of *C. macrospira* a few specimens that approach more closely to the form here described, and this fact suggests the question whether there are really two species, or only varieties of one variable species.

Locality.—Wettacombe's ranch, near Musselshell River, in the vicinity of Harlowton, Montana.

Horizon.—Upper part of Lower Cretaceous or base of Upper Cretaceous.

GONIOBASIS? ORTMANNI n. sp. Pl. IV, Figs. 7–10.

Shell small, moderately slender, consisting of about six convex whorls; aperture elongate ovate, slightly produced below; inner lip somewhat thickened, closely appressed to last whorl above, slightly reflexed below so as to partly cover the small umbilical chink; surface bearing inconspicuous growth-lines, usually crossed by a variable number of much more prominent sharply elevated spiral lines, which in some cases are strong enough to be called small carinæ. Specimens which may be considered to have the average or typical sculpture show four spiral lines on the whorls of the spire, with about six additional on the base of the last whorl

[1] Named by Meek in a list without description in *Rept. U. S. Geol. Surv. Terr.*, for 1872, p. 478. Described in 1877, *U. S. Geol. Expl. 40th Parallel*, Vol. IV, pt. 1, p. 180, with figures of a small shell doubtfully referred to the species. Figures of Meek's original type are published by White, *Twelfth Ann. Rept. U. S. Geol. Surv. Terr.*, Pl. 30, Fig. 2*a*; *Third Ann. Rept. U. S. Geol. Surv.*, Pl. 8, Figs. 6, 7, and *Bull. U. S. Geol. Surv.*, No. 128, Pl. 10, Figs. 2, 3.

and sometimes a few finer intermediate lines. A few individuals show five lines on the spire, while others have only three or two. Smooth forms like that represented by Fig. 10 usually show incipient spiral lines on the last whorl.

Height of an average specimen, about 17 mm.; greatest breadth, 8 mm.; height of aperture, 7 mm.; breadth of aperture, 5 mm.

The most striking feature of the species is the variability of its sculpture, though in this respect is comparable with such living species as *G. virginica* Gmelin. Of about 200 specimens in the collection nearly half either lack spiral sculpture or have it very faintly developed.

The generic reference of Goniobasis is not entirely satisfactory, as the aperture differs in some respects from typical living species of the genus. It slightly suggests *Lioplacodes veternus* Meek from the supposed Jurassic at the head of Wind River, but it is specifically very distinct and I think not referable to the same genus. In sculpture it resembles *G. tenuicarinata* M. and H. from the Laramie more closely than any other fossil form.

Locality.—Wettacombe's ranch near Musselshell River, in the vicinity of Harlowton, Montana.

Horizon.—Upper part of Lower Cretaceous or base of Upper Cretaceous.

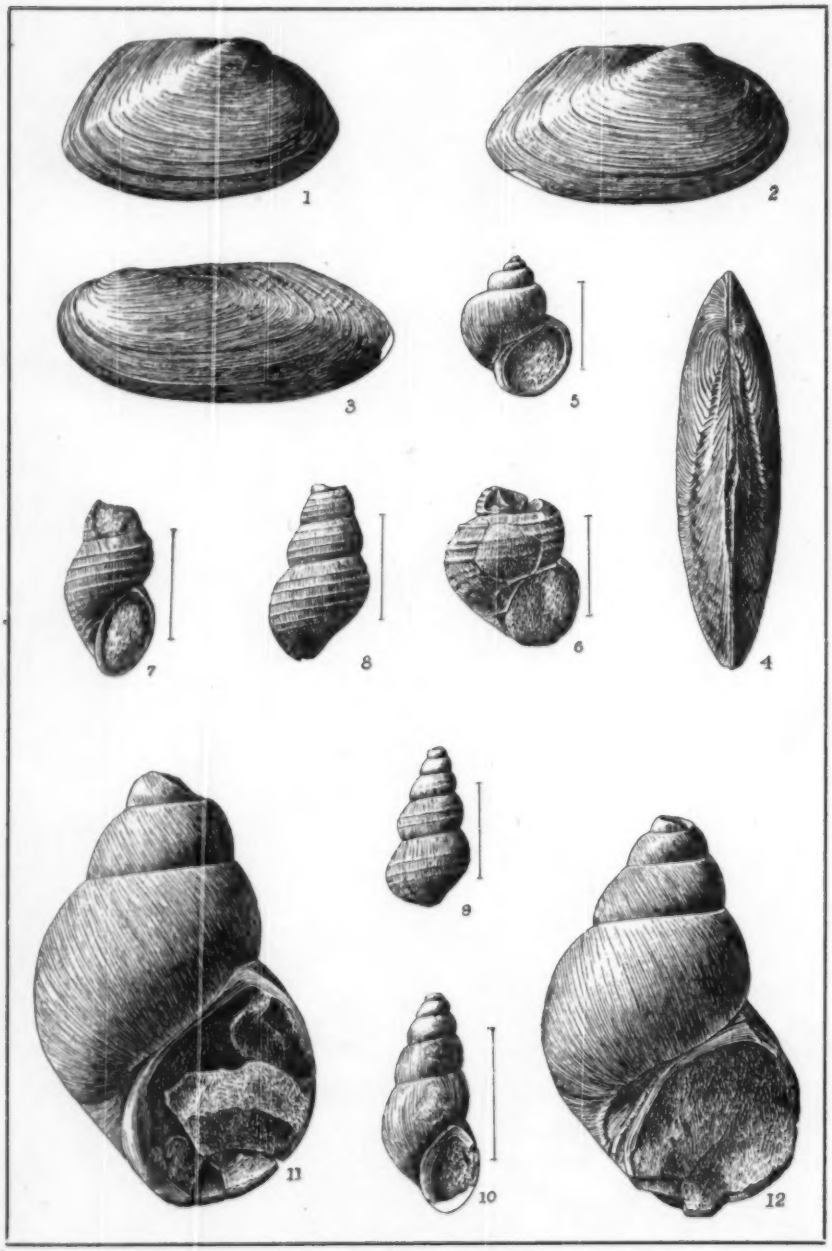
GONIOBASIS? SILBERLINGI n. sp. Pl. IV, Fig. 6.

A single fragmentary specimen associated with the preceding seems to be worthy of description, although the generic reference is very doubtful. It is the basal portion of a shell consisting of nearly two whorls and may be described as follows:

Shell of moderate size, rather stout; whorls very convex; aperture broadly ovate; inner lip thin, slightly reflexed below over a distinct umbilical pit; surface of the spire with four strong spiral ridges or carinæ, which are unequally spaced, the space between the uppermost one and the suture and also between it and its neighbor being broader than the other smooth bands.

The fragment measures 13 mm. in height and 13 mm. in greatest breadth; height of aperture, partly estimated, 9 mm.; breadth of same, 6 mm.

The base of the aperture is broken, and it is possible that the large size of the umbilical pit is due to abnormal individual development. If this is a normal example of the species, it can hardly



STANTON—NEW FRESH-WATER MOLLUSCAN FAUNULE.

be placed in the same genus with *G.? ortmanni*. In sculpture it suggests the carinated forms that White has very doubtfully referred to *Lioplax endlichi* from the Bear River formation.

Locality.—Wettacombe's ranch, near Musselshell River, in the vicinity of Harlowton, Montana.

Horizon.—Upper part of Lower Cretaceous or base of Upper Cretaceous.

EXPLANATION OF PLATE.

Unio farri Stanton.

Fig. 1. Right valve of type.

Fig. 2. Right valve of compressed form, probably male.

Unio douglassi Stantor

Fig. 3. Left valve of a small specimen.

Fig. 4. Dorsal view of an average-sized specimen.

Viviparus montanaensis Stanton.

Fig. 5. Aperture view of the type, enlarged.

Goniobasis? silberlingi Stanton.

Fig. 6. Aperture view of the type, enlarged.

Goniobasis? ortmanni Stanton.

Fig. 7. Aperture view of fragmentary specimen with strong sculpture, enlarged. Outer lip restored from another specimen.

Fig. 8. Dorsal view of a similar specimen, enlarged.

Fig. 9. A specimen with only two spiral lines on the spire, enlarged.

Fig. 10. Aperture view of a specimen without spiral sculpture except on back of last whorl, enlarged.

Campeloma harlowtonensis Stanton.

Fig. 11. Aperture view of the type.

Fig. 12. Similar view of a broader, more umbilicated specimen.

REACTION AS AN EFFICIENT AGENT IN PROCURING DEEPER NAVIGABLE CHANNELS IN THE IMPROVEMENT OF RIVERS AND HARBORS.

BY LEWIS M. HAUPT, A.M., C.E.

(*Read April 2, 1903.*)

Consumption, production and distribution are the three main elements of trade. Without great facilities for distribution it is not possible to maintain a nice adjustment between supply and demand. One section of the earth may be starving, while another may be burning its excess of food for lack of cheap transportation.

The question, therefore, has its humane as well as its financial and scientific aspects. It is the aim of the engineer and the capitalist to reduce the cost of transportation to a minimum for the general welfare of mankind.

The great improvements which have been effected in the railways of the world have resulted in a rapid reduction in the average rates of freight, which are still falling. Roadmakers have caught the infection and are mending their ways as rapidly as the means become available. Sailing vessels are transformed into the schooner type of greater dimensions and are designed to be handled by smaller crews, so that it may be said they represent the cheapest class of carriers. The steamer also is being greatly enlarged in its capacity with the same end in view, but it has not and cannot reach the limit of its economic possibilities because of the absence of adequate channels at its terminals.

These great evolutions in transportation have been made possible in the United States by the concentration of mind, money and materials, working in harmony and resulting in a system of overland movements which is without a rival. It is the outgrowth of private capital, employed to develop limited areas, but gradually consolidated into trunk lines, and which finally, assisted by the National Government, united the two oceans. The merging of these great interests still continues and the end is not yet. These bands of steel have enabled our excess of production to reach the seaboard and be distributed to foreign markets, and it may not be out of order to glance very briefly at the magnitude of this movement.

Thanks to a beneficent Providence and the industry and intelligence of our people, our exports exceed our imports by an amount greater than that of all other nations. Their increase within a generation is startling. While the population has doubled in the past thirty years, the per capita of money has increased from $17.50 to $28.66.[1] The number of artisans has increased 2.7 times, while his average earnings have risen from $387 to $500 per capita per annum. The capital employed has expanded fivefold and the value of the output more than threefold. In consequence the per capita of our exports has increased in this same period from $7.29 to $13.81, of which the largest part is food-stuffs.

The increase in agricultural exports was over 300 per cent., and that of manufactures 750 per cent., so that this country heads the

[1] O. P. Austin, Chief of the Bureau of Statistics, in *The World's Work*.

list of exporting nations, having reached nearly one and a half billion dollars in 1901. The United States produces more wheat than any other country of the world; more corn than all other countries combined; more beef and pork than any other; three-fourths of the world's supply of cotton; of coal our exports exceed those of any other nation, and at far less cost. We are the mainstay of the world for petroleum for light, heat and other purposes, and we lead in the quantity and value of manufactured articles.[1]

For the internal distribution of the nearly 900,000,000 tons of traffic, resulting from our splendid resources and energies, we have over 200,000 miles of railways, or more than two-fifths of the world's mileage, to say nothing of the superior facilities for the distribution of thought by mail, telephone and telegraph. Thus it is seen that, although the population of the country has doubled within thirty years, the productivity of the nation has far exceeded this ratio, and that it is the main reliance of Europe for many of its necessities. Our importance as a base of supplies for the Orient is also rapidly increasing, and it is reasonable to suppose that the next generation will realize even greater developments than this.

The present year heralds the preparation which the great masters of transportation are making for "round-the-world" lines by the consolidation of the ocean carriers into the International Mercantile Marine Company, so that our exports may be delivered in vessels under domestic control at less cost, and our heavy freight bills to foreign flags be reduced. This is as it should be, and every possible encouragement should be given to all legitimate efforts to increase the circulation of material products and to reduce the cost, thus extending the market-range. But the mere multiplication in the number of vessels does not lower the cost unless it develops a keen competition between rivals. This competition is to some extent neutralized by combination, but under good management this effect may be more than offset by the reduction in fixed charges and by the use of vessels of greater tonnage, which can be operated at less cost per ton of cargo transported.

This brings us directly to the crux of the argument, for the vessels, having already outgrown their channels are obliged to await favorable conditions, clear with partial cargoes or lighter; in every case adding to the cost at the expense of the consumer, or restricting deliveries. It has been predicted that ere long vessels of 1000

[1] O. P. Austin, Statistician, Treasury Department, Washington.

feet length and forty or more feet draft would be upon us, but this economic ideal cannot be realized until some better method is developed for the creation and maintenance of much deeper channels. To meet this demand for deeper water more powerful dredges are building, in the hope of combatting successfully with the ceaseless activities of the bar-building elements, by sporadic mechanical devices, costing large sums to operate and offering serious obstacles to navigation by their presence in narrow channels. With the exception of Port Royal, with twenty-one feet; Gedney's Channel, with twenty-three feet; the Golden Gate, with thirty-two feet, and the Columbia Bar, with nineteen feet, the natural depth of scour over our alluvial bars seldom exceeds fifteen feet, and is more frequently limited to from three to twelve; while a modern vessel, fully laden, may draw thirty-two, and should have a channel depth of from thirty-five to forty feet for safe passage over a rough bar at low water. Hence the urgent demands made upon the national treasury for larger appropriations, that at least the most important of our railroad and commercial terminals may utilize these economies in transportation.

For the forty-four years prior to 1866, when our commerce was carried in much lighter-draft vessels, the total expenditure for waterway improvements was but $14,990,170; but between 1867 and 1901 they expanded to $332,487,627—making a grand total to that date of $347,477,897, to which should be added the appropriations of the last Congress of about $60,000,000 more, thus swelling the aggregate to over $400,000,000. In reporting the last bill the Chairman of the River and Harbor Committee stated that "the total amount which would be required for the completion of projects for river and harbor works . . . now considerably exceeds $300,000,000." If but ten per cent. of this sum can be secured annually it is evident that our commerce must "drag its slow length along" for many years, while the increase in the demand for greater facilities cannot be met unless greater efficiency may be secured in the methods in vogue.

During the score of years succeeding 1867 the average expenditures were $4,480,000, but soon thereafter, when deeper channels were demanded and the use of the submerged and twin jetties supplemented by dredging became the main reliance, the annual average reached nearly $13,000,000, with a rapidly increasing ratio. In the past quarter century the estimates and expenditures at only

eight of our most important seaports, where jetties have been built or proposed for channels of modern depth, foot up to $50,515,784, but the difficulty of securing the depth has necessitated in such cases a resort to dredging to create and maintain the channel. These new conditions have resulted in the construction of powerful sea-going hydraulic dredges with great capacity, and have in a measure revolutionized the practice of deepening by scour, as it is considered by some more economical to use the dredge without regulating works. In consequence it is found that the amounts expended and estimated to complete the approved projects at only four of our principal ports by dredging alone will aggregate $41,396,129, exclusive of the large additional sums required for maintenance.

In view, therefore, of the important interests involved, the unreliability of dredged channels, the inadequacy of twin jetties and the great cost, it would seem pertinent to inquire whether the profession of engineering has reached its ultimatum in this department of science. Is it not possible to utilize to greater extent the boundless resources of nature for the purpose of creating deeper channels at our ports?

The magnitude of these forces will be better understood when it is shown that the sun as a prime mover evaporates approximately 15,000 tons from each square mile of the ocean's surface every twenty-four hours, so that his daily work upon the 150,000,000 miles of water surface represents a load of two and a quarter trillion tons, a large portion of which is carried by the wind-driven clouds to the land where it is recondensed. Assuming the precipitation to be proportional to the ratio of land to water, there would be 562 billion tons falling on the land surface, and taking the run-off at but 40 per cent., there results 225 billion tons of stored energy flowing down to the sea every day of the year, or, reducing this weight to its volumetric equivalent, we have nearly fifty cubic miles or 264,000 square miles of water one foot deep, an area greater than the State of Texas.

This is the fluid solvent which, in the laboratory of nature, is daily applied to earth-sculpture, while the portion at work in the chemical and metallurgical laboratories of the interior is much greater than this. The former is all that is available for the avenues of domestic commerce, while the latter is the part which contributes to its tonnage by developing its products.

For the foreign commerce there is the illimitable ocean with its dynamics—the tides, winds and currents—which are not yet fully understood nor utilized.

The poet Milton has aptly said :

> " Accuse not Nature, she hath done her part;
> Do thou but thine."

This prompts the question, How? It is to answer this query that attention will be briefly directed.

It is well known that engineering, like many other sciences, is largely empirical, and that more is learned from failures than from successes, for failures are the buoys which mark the channel to success. It becomes important, therefore, to review the experiences of the past, in which this country is particularly rich, that their lessons may guide us in preparing to satisfy the demands of the future. With this end in mind, a brief review will be made of a few types of harbor improvements, showing their physical features and results, and the methods which have produced them.

Existing Methods.

The devices in use to-day for the alleviation of the evils of ocean bars are twin jetties, dredging and dynamite, either singly or combined. The theory of the two-jetty system has been so long and ably discussed that little need be added further than to state that it is based upon the idea of preventing a dispersion of the currents by the building up of parallel or convergent training walls to concentrate the discharge upon a single path across the bar.

The objections to this system are that, being built out from shore, the confined waters are projected upon the inner slope of the bar, which is pressed seaward as they advance. Moreover, being at a fixed distance apart, they cannot be adapted to great ranges of stage, for if adjusted to a normal low-water discharge they will be too close to pass the floods without retardation, or the reverse. In any case there must result a sedimentation above, within or beyond the works, as will be shown later, and dredging must be applied for relief, and, furthermore, they reduce the tidal influx. Until within a few years twin jetties aided by dredging have been the panacea for all classes of harbor bars, regardless of the relations between deposits, discharge and the many other conditions affecting their

formation and maintenance. It is important that a careful diagnosis be made of each case to ascertain its preponderating element.

Physical Considerations.

Thus it is seen that the physical agencies become of fundamental importance, and that a clear distinction must be made between bars formed from littoral drift and those formed from the detritus carried down by streams. For tidal inlets it is also important to ascertain the prevailing direction of the littoral movements which have frequently but erroneously been supposed to follow the prevailing winds, whereas it is more frequently found to be the resultant of the configuration of the adjacent coast line and of the angular wave movements, especially during the flood tide, when the waves are most heavily charged with silt.

Knowing the direction of this general resultant, the engineer can then determine on which side of the channel his protecting work should be placed, although there still seems to be a radical difference of opinion as to whether it should be on the near or far side, for only recently it was recommended that if a single jetty were built at a certain inlet on the Southern coast, it should "be located on the south of the channel, since the drifting sands come from the north. At this place, however, while the drift is comparatively slow, it is an enormous sand bank which moves, and which always moves very positively in one direction, and it is difficult to see how such a constant force from the north could avoid crowding the channel close to the jetty." The jetty plan was therefore rejected. Frequent experience in the construction of two jetties, where the farther one has been built in advance of the nearer one, has served to show the fallacy of this location and order of procedure.

The requirements to be met at tidal inlets are, free admission of the flood tide as the only source of ebb energy, protection of the bar channel from the prevailing direction of the littoral drift, conservation of ebb tide as it passes seaward over a narrower path on the bar, development of its potential energy in useful work locally on the bar crest and an automatic adjustment to any stages of wind or tide. All of these may be better fulfilled generally by one jetty than by two, and manifestly at about half the cost. These results are rendered possible by placing in the way of the ebb current a curved resisting medium in such position as to maintain a continuous reaction along its concave face. In fine, this structure be-

comes the tool for the conversion of the effluent energy into useful work, with lateral transportation of the eroded material.

Reaction versus Velocity.

The opinion is prevalent that the deep pockets frequently observed at the ends of spurs or obstacles or at contractions in rivers are due to velocity, and it has been stated that because a mean ebb velocity of two feet per second maintains a depth of over 100 feet at the Narrows of New York Harbor, therefore a similar contraction on the bar near Sandy Hook would produce some such depths. This was made the basis in 1886 for a proposition to build a jetty nearly five miles long, closing three of the channels across the New York bar. The great depth at the Narrows is not a velocity but a reaction depth, due to the resistance which the converging shores oppose to the passage of the flood, not the ebb tide, which increases the head before reaching the pass, depressing the resultant to the bottom, from which it reacts and scours out a depth to compensate for the lateral contraction. At other points in the harbor velocities of more than two feet per second do not scour to depths exceeding three feet, so that the results must be ascribed to some other cause than mere velocity.

An extended investigation of these abnormal depths leads to the conclusion that they are caused by eddies operating in a vertical plane, these eddies being caused by obstacles placed in the path of a current in such manner as to retard the flow by the interference due to converging forces, thus creating a head with a downward resultant and scour until compensation is secured by enlarged aperture. Here the reaction produces a change of direction of the resultant, which is deflected upward with dispersion of energy, deposit of material and ultimately restored equilibrium. These facts are doubtless well known to many observers, but the particular point to which attention is directed in this connection is that the downward movement producing scour is supplemented necessarily by the upward resultant, accompanied by deposit in the same vertical plane, so that whichever way the eddy operates, whether with flood or ebb, the bar is a sequence of the pocket, unless other forces come to the rescue. Thus it appears that an eddy both scours and deposits. These effects are reciprocal results of the same eddy, and not of two separate ones. But eddies also operate in horizontal planes, and with like results. When the obstacle is limited in extent the effect

is local, but when the resistance is maintained the reaction continues to be developed and the energy to be expended until the resistance ceases.

The great advantages resulting from a continous reaction produced by a concave directrix appears to have been largely ignored in the work of river and harbor improvement, and yet the location of the best channels under the concave banks of rivers attests its value to commerce. It is true that numerous curved dikes and revetments have been placed in the concave bends of rivers, but the object has been to protect them *from* erosion and not to encourage it. Their value as tools to cut away an ocean bar does not appear to be fully appreciated, since where single curved jetties have been built the convex face has generally been turned to the current, to encourage, as has been said, the tendency which water has to follow a convex curve. (?)

The concave directrix has also the great advantage of maintaining the head due to centrifugal force and thus changing the direction of the resultant downwardly, producing the lateral scour and resulting convex bank or counterscarp created by the stream acting as an hydraulic auger, and of automatically adjusting this counterpart to the variable requirements of its regimen.

These general principles will be more fully elucidated by illustrations selected from surveys and models, showing the holes bored by reaction and the shifting of channels by artificial works, which are instructive as to the intimate relation between cause and effect.

A study of the natural effects found to exist under certain conditions enables the engineer to predict with some assurance the results which may follow a utilization of the available forces at any site. One of the most instructive examples of the vertical eddy is to be seen in the Narrows at New York, to which reference has already been made. Here the bottom currents are with the flood tide for about eleven hours out of the twelve, and this resultant flood extends as far up as the Battery. The ebb resultants are greatest at the surface and diminish rapidly with the depth, reaching their point of reversion at or near forty feet in the Narrows. On the bar the ebb currents show a feeble resultant at a depth of less than twenty-four feet in but one of the channels.

The remarkable "slue" which has maintained its position athwart the path of the currents since the earliest surveys has excited some attention as to its phenomenal position and depth of fifty-two feet.

It is referred to in the early Coast Survey Reports, and was made the subject of a special paper by the late honored member of this Society, Prof. Henry Mitchell, who prepared a manuscript report upon it, in connection with the physics of the lower bay, in 1858, but which was not published. It serves to confirm the claims of this paper that depths may be and frequently are the result of eddying action rather than velocity. The confluence of three currents produces a resultant having a northeasterly set which impinges upon the bar at the head of Gedney's Channel and is deflected thence by this resisting bank of sand northwardly, boring out the slue for a length of a mile and a width of a half mile. The latest survey shows a depth of fifty-three feet, with but eighteen feet on either flank. It was proposed at one time to change the direction of this resultant by cutting off one of its components and training the currents seaward to open Gedney's Channel by the utilization of this force, but it was not accepted. Again, the reaction at the head of Sandy Hook has produced a maximum depth of sixty-eight feet, diminishing within about a mile to thirty feet, while abreast of the point and a half mile distant the depth is but sixteen feet.

The construction of the old Breakwater at the mouth of the Delaware in 1828 furnishes some instructive lessons as to the changes effected by obstacles placed in a tideway. Here, at the ends of the ice-breaker and of the breakwater, are to be found the characteristic deep holes resulting from the head generated by the resisting structures. At the gap the pockets are on the outside of the opening, and the depths are the effects of the flood-tide. Both of these pockets are fifty feet deep, and the material scoured out from them has been carried into the harbor and deposited in the lee of the structures, making a shoal with only ten feet at one point. At the southeastern end of the breakwater the ebb reaction has scoured to a depth of fifty-four feet, while at the western end of the ice-breaker the hole is due to the flood, and is limited to about forty feet. Moreover, the diagrams of velocity curves show that in the centre of the harbor, where the maximum velocity of the ebb is six feet per second, the bottom has not been prevented from shoaling to about fifteen feet, while a similar ebb velocity at the "gorge" is able to maintain depths of thirty feet. If these depths are due solely to velocities they should be equal, since like causes should produce like effects.

Numerous other instances of these abnormal depths due to reac-

tion, and not to velocity simply, might be cited, but a few must suffice.

In the Thoroughfare at Longport, N. J., the landing pier has caused a hole forty-eight feet deep, while 800 feet away there was a bar bare at low water, but covered by a tidal current almost as swift as that past the pier.

In the Charleston gorge the maximum depth was eighty-two feet, while on the bar seaward thereof the depth was zero, and the best crossing was six miles south of the gorge. At Fernandina (Cumberland Sound), Ga., the maximum depth at the head of Amelia Island, projecting into the channel, was sixty feet, and abreast of it bare at low water.

The Galveston gorge shows about fifty-eight feet, while the normal bar depths were twelve to thirteen. The St. John's river, Fla., swings to the sea through a radius of one mile, carrying a maximum depth of fifty and three-tenths feet, and as the axis straightens to a tangent the depth diminishes to twenty feet. It then strikes a jetty at an abrupt angle which develops its latent energy and scours to fifty and two-tenths feet, but as this is not maintained by the convex curve of the jetty, the channel deteriorates to about eleven feet.

The building of a spur in the Mississippi river at right angles to the bank had the effect of increasing the depth from twelve to nearly one hundred feet in consequence of the violent eddy which was created, and now that the spur is covered and the river has assumed a new regimen, the depth has shoaled to about thirty feet, which is maintained.

From these few instances it would seem to be a fair inference that depths may be developed quite as well by single lines of concave directing works as by two, if proper attention is given to the volume of affluent as well as to the relative amount and direction of the motion of the bar-building materials.

Practical Suggestions.

In view of the requirements as previously stated, it is evident that to protect the proposed channel from the littoral drift a submerged low-tide or half-tide jetty will not suffice to arrest this drift, but it should extend above the highest tide. It must also be placed between the channel and the source of the prevailing drift, just as a

snow- or a sand-fence must be placed to "windward" to protect a rail- or wagon-way.

It must be curved, concave to the effluent currents, to develop a continuous reaction, and should be constructed inward from the outward slope of the bar, to avoid the advance of the crest and to utilize the force of gravity in cutting shoreward and downward, instead of seaward and upward. These are some of the conditions which give promise of the greatest results attainable at a given location. Taking now a few typical illustrations of the several methods in vogue, it is seen that the New York entrance is to be deepened by dredging some 42,000,000 cubic yards from the bar, beginning at the easterly end of Ambrose Channel, at a cost of about $4,000,000, but with no definite time limit.

Although this sector of the bar shows a remarkable degree of permanency, it can hardly be expected that the formation of this deep cut, created by artificial means in the open sea, at a point where the natural depths are steadily maintained at from sixteen to eighteen feet, will long remain open. If it be assumed that normal conditions would be restored, say, in a period of ten years, it would represent an annual accretion of about 4,000,000 cubic yards to be removed by dredging, which at the present price would cost $360,000, or the interest at three per cent. on $12,000,000. For a much smaller sum it would be possible to train the currents through this new and shorter channel by permanent works which would maintain it and at the same time become a valuable aid to navigation.

The effects of the submerged jetty type is best seen at Charleston, where the littoral drift is southward. Here the outer ends of the jetties are raised above high water, but the shore flanks are far below the surface, to admit the tides freely. The result is that the beach sand travels across them and forms shoals within the harbor, while it also travels around the outer end and maintains a bar in the open sea more than half a mile beyond the works, through which the channel must be maintained by dredging.

At Galveston, where the submerged plan was modified to reach above high water, the building out of the south jetty first has caused the bar to advance some three miles, adding that length to each of the jetties, which are 7000 feet apart, and a new bar is forming across the mouth in the lee of the north jetty. The channel must also be maintained by dredging.

At the mouth of a sedimentary river, like the Mississippi, where

the silt comes from within, two jetties give much greater promise of success, and the great work of Captain James B. Eads in opening the South Pass by parallel jetties curving to the westward has proven to be a boon to the country. These jetties were built under adverse conditions, as payments were conditioned upon results to be secured, and as the first pair of jetties did not suffice to give the requisite depth, it became necessary to build spurs, then a second line of works, and finally a second series of spurs before the legal depths were obtained. This, however, resulted in an over-contraction of that outlet, and has caused the retarded currents to drop their sediment in the Pass above the jetties instead of beyond them, involving dredging.

Probably the most successful work of this kind at a river's mouth is that completed at the mouth of the Panuca river, Tampico, Mexico, where in two years' time two parallel straight jetties were constructed about a mile and a quarter long across a bar, having depths varying from five to twelve feet, and as soon as they were finished a severe flood flushed the channel so completely that the depths of twenty-seven feet have remained ever since, the littoral current here being sufficiently strong to remove the sediment carried out beyond the jetties. The engineer of this work was E. L. Costhell, C.E.

At Aransas Pass, a purely tidal inlet on the Texas coast, a single reaction breakwater, in an incomplete condition, has produced a progressive deepening by the control of feeble tides, unaided by dredging, and at a cost of less than one-third that of the estimated project, thus fully demonstrating the great practical utility of the single reaction jetty system at the only point where an opportunity has been afforded for a test on a large scale in this country, after about fifteen years of persistent effort The Consulting Engineers of this work were Messrs. H. C. Ripley, Geo. Y. Wisner, and the writer.

THE WARFARE AGAINST TUBERCULOSIS.

BY MAZYCK P. RAVENEL, M.D.

(*Read April 4, 1903.*)

It would seem almost superfluous to dwell on the terrible destruction of human life due to tuberculosis, or to dilate on the urgent necessity that exists for general and combined efforts to lessen its ravages; yet, in spite of all that has been said and written on the subject during the last ten years, and in spite of certain encouraging signs of awakening interest in the public mind, it is still true that there exists a lamentable and inexplicable apathy in regard to this scourge of the human race. Philanthropists are lavish in their gifts to colleges, hospitals, libraries, museums and such like institutions, yet in America at least there have been very few substantial donations toward the eradication of tuberculosis, though it would be hard to imagine a greater boon to stricken humanity than the accomplishment of this end. Legislators give freely to all kinds of charitable institutions, but the amount given to the army of the tuberculous is pitiably small. This attitude of legislators may to a great extent be taken as indicative of public sentiment. This sentiment becomes harder to understand when we consider that three facts have been absolutely demonstrated in regard to the disease: 1. It is communicable. 2. It is preventible. 3. In the early stages it is curable.

It is well to inquire into the causes of this lack of interest, and see if there is sound reason for them. One of the greatest drawbacks has been the persistent belief in the hereditary character of the disease, which is even now quite prevalent among the masses, and held by many physicians. While it has been shown that tuberculosis may be transmitted in this manner, it has been equally proven that it is of very rare occurrence, and practically negligible. Among the lower animals healthy offspring may be constantly obtained from tuberculous mothers by separation at birth and artificial feeding—a plan carried out on a large scale in Denmark by Prof. Bang. It is, however, true that tuberculosis runs in families, the reason being that the children of phthisical parents are constantly exposed to infection. In man only some twenty cases of true hereditary tuberculosis are on record (Osler), and in cattle there are less than 100 to be found in the literature. Another obstacle to progress is the inevi-

table tendency of the human mind to grow accustomed to danger. We have grown accustomed to the death-rate from tuberculosis, and do not realize what it means. A panic would be caused in any one of our large cities by 100 deaths from cholera, yellow fever or plague, yet in New York 10,000 deaths and in Philadelphia 2800 deaths are caused each year by tuberculosis without exciting even passing comment from the average person. The only real difference is that tuberculosis is with us always, demanding its lion's share of victims with each recurring year, while the other diseases are rare visitors.

The total number of deaths in the United States each year from tuberculosis is estimated at 150,000, which means a money loss of $330,000,000 to the country. This should be sufficient reason for preventive measures on our part, even if we leave out of consideration the distress of the victims and their families. The slow and insidious onset of tuberculosis no doubt tends to lessen the fear we have of it, but in this very fact lies much danger, since it is more difficult to persuade persons of the relation of cause and effect than in a malady where exposure is promptly followed by attack. The magnitude of the task deters some from undertaking it. Very recently a legislator who was being urged to assist in procuring State aid brought up such an objection. The task is unquestionably a great one, but it can be stated with assurance that the total eradication of tuberculosis is feasible.

Another class of obstructionists are those persons who regard all discoveries as "new-fangled notions," and quote the mode of life of their grandfathers, who did not find measures for the prevention of tuberculosis necessary. It is impossible to argue with such persons, as a rule. It may be pointed out, however, that tuberculosis is essentially a disease spread by overcrowding, and, like all communicable diseases, the more dense the population the greater necessity for preventive measures. Conditions change materially with increase of population, and the new conditions must be met by new measures which may have been unnecessary before.

Prevention of Tuberculosis.

All efforts at the eradication of tuberculosis to be successful must be based on the fundamental fact of its communicability, and in the main it is to be treated as the other contagious diseases, though

the restrictions need not be so severe, since more or less prolonged exposure is necessary to bring about infection.

Two parties are to be considered, the tuberculous person and the community, and while the former is entitled to every consideration and attention, the good of society in general must be the principal consideration which guides our actions. Fortunately, the interests of the two parties are not irreconcilable, and much can be done by education to smooth the difficulties which lie in our path. With this end in view there should be in every State, and in all large cities, societies whose object is the study of methods of prevention, and the dissemination of such knowledge in short, plainly written tracts among the people. In addition to this, Boards of Health should issue circulars constantly giving such information and advice. At present only twenty-two States and seven cities issue such circulars and recommendations, while five States have State societies and five cities have local societies for the prevention of tuberculosis. These societies can do much good also by shaping legislation. States and cities should have uniform laws regarding expectoration in public conveyances, buildings and on sidewalks, overcrowding of factories and tenement-houses, the construction of such buildings as regards light and ventilation, and the employment of children under age. Health officers should have the power to force ignorant and vicious tubercular persons who persist in reckless expectoration and other offenses against public hygiene into hospitals provided for them by the public. There should be notification and registration of the persons suffering from phthisis, and apartments occupied by such persons should be thoroughly disinfected periodically, and always after death or vacation of the premises before new tenants are allowed to enter them.

All of these things can be carried out with little or no increase of expense, and much good can be accomplished along these lines. However, the urgent need is for institutions in which the sick can be cared for and instructed. These should be of at least two types :— sanatoria, built in open country districts in regions known to be specially adapted to the treatment of tuberculosis; and, second, hospitals in or near cities for the hopelessly ill and destitute, where the maximum of comfort can be given them, and where they will cease to be sources of infection to their families and the public in general. In connection with the sanatoria convalescent farms are most useful, and may be made self-sustaining to a certain extent. On

such farms patients who are well enough to be discharged from the sanatoria can find light employment under good conditions until strong enough to return to their usual avocations in factories, etc., without danger of relapse.

I have not tried to outline an ideal method of dealing with tuberculosis, and much could be added to what has been said, but have limited myself to what appears to me imperatively demanded by the conditions which confront us, and to what is entirely in our power to effect. The affair is, however, beyond private charity, and governmental aid is necessary, each State doing its share.

In spite of the enormous expenditure which would be involved in providing hospital accommodations for the indigent tuberculous, it would cost less than the present money loss to the country from deaths alone, estimated, as said before, at $330,000,000 annually; and in a few years we could confidently expect a marked and progressive decrease in outlay. It must be borne in mind that the demonstration of the communicability of tuberculosis has resulted in special hardships to the poor consumptive, since most general hospitals now close their doors to these afflicted ones. The poor consumptive reaps but little aid from the vast donations from public and private sources to general hospitals; hence the urgent necessity for special provision for them, both on the score of humanity as well as protection to the public health.

Hand in hand with such measures should go efforts directed to the eradication of tuberculosis from cattle, since we must look on cattle as the source from which a certain amount of human tuberculosis springs, chiefly in children.

Without entering into matters of controversy, the following proven facts may be stated as grounds for this belief:

(1) The tubercle bacillus as found in bovine animals differs from that found in man chiefly in its greater virulence for practically all experimental animals, including man's nearest relative, the monkey. It would be an anomaly if man, one of the most susceptible of all animals to tuberculosis, were immune to the most powerful type of the germ of tuberculosis known to us.

(2) There are numerous well-authenticated cases of accidental inoculation of man by the bovine tubercle bacillus, with the production of typical disease at the point of inoculation. Some of these cases have been followed by general tuberculosis, ending in death, attributable with good reason to the inoculation.

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(3) A number of instances have been recorded in which the onset of tuberculosis followed the use of milk from tuberculous cows. In some of these the relation of cause and effect is so close that Nocard has well said "they have almost the value of an experiment."

(4) That food containing bovine tubercle bacilli may and does produce tuberculosis in man seems already proven by finding in the intestinal tract (mesenteric glands) of children who have died of tuberculosis tubercle bacilli which have all the characteristics of the bovine germ, and which have an intense degree of virulence for cattle.

(5) The close relationship of the human and bovine tubercle bacilli has been shown by the recent experiments in immunization, in which it has been proven that injections of bacilli from human sources will protect animals against virulent bovine germs. This has been done by Trudeau, De Schweinitz, and Pearson and Gilliland in this country, and by Behring and Thomassen in Europe.

What Has Been Done in the United States Toward the Suppression of Tuberculosis.

Three States and four cities require the reporting of cases of tuberculosis; in five States and five cities report is optional; in one city it is under litigation.

Two States have general anti-spitting laws, while five States have local laws, and fourteen cities have their own laws. Twenty-two States and seven cities issue circulars and recommendations.

The United States Government has two sanatoria for persons in its employ; five States have five special institutions, and nine States have projected sanatoria. Two States have tent colonies on a small scale. Only three cities have special municipal hospitals for consumptives. There are forty-two private institutions in eleven States, some supported by private charity, some partially self-supporting, and some for pay patients only.

Twenty States and twelve cities have laws regarding bovine tuberculosis. Twenty States have done nothing in regard to human or bovine tuberculosis; six States have done something to combat tuberculosis in man only, and eight States have done something against bovine tuberculosis alone.[1]

[1] These figures have been taken almost entirely from the valuable paper of Dr. S. A. Knopf, read before the American Medical Association at Saratoga, June, 1902. Since then considerable advance has been made.

Comparisons are said to be odious, but in the hope of stirring up our people in the United States, I quote the most recent statistics of what is being done in Germany, which may be taken as an index of the attitude of most of the countries of Europe toward the scourge of tuberculosis.

The Fight Against Tuberculosis in Germany.

According to the Imperial Health Office in Berlin, the deaths from tuberculosis are about one-tenth of those of all diseases. In 1899 the number of patients treated in hospitals in the empire was 226,000. According to the latest statistics there are at present 57 public sanatoriums for the tuberculous in Germany, of which 34 are located in Prussia, 6 in Bavaria, 2 in Saxony, 1 in Wurtemberg, 1 in Hessen, 1 in Sachsen-Weimar, 1 in Thuringia, 1 in Reichsland, 3 in Baden, 2 in Brunswick and 5 in the Hansa cities. Besides these there are 4 four institutions near the sea—namely, Nordeney, Wyk, Gross-Muritz, Zoppot. There are also 23 public sanatoriums nearly completed, among these being Buch, near Berlin. The city of Berlin has at the present time 3 public sanatoriums—namely, Malchow, Blankenfelde, Gutergotz. There are also 20 private German sanatoriums, and 1 in Davos (Switzerland). In the 78 sanatoriums for the tuberculous there are 7000 beds. If we calculate that each bed is used by four persons in the course of a year, we find that about 30,000 tuberculous patients annually enjoy the benefit of treatment in the sanatoriums. The efforts made in the German Empire to combat tuberculosis, both by direct regulations and by general preventive measures, are being actively carried on. In particular, the Imperial Government, the governments of the different States, the executive authorities, the national insurance institutions and the municipal governments are seriously and actively participating in this work. The result of these efforts, which have been now carried on for some years, is already noticeable in a decrease in the number of deaths from tuberculosis, which in the future will be still more marked (*American Medicine*, March 21, 1903).

Artificial Immunity and Serum-Therapy.

For many years constant effort has been made to discover a serum or lymph for the specific treatment of tuberculosis, and several such substances have been announced from time to time. All of them

have proved disappointing, however, not excepting Koch's lymph or tuberculin, the discovery of which was hailed with delight and enthusiasm by physicians and consumptives alike in all parts of the world. Recently it has been demonstrated authoritatively that it is perfectly possible to produce artificial immunity against tuberculosis in animals by a process of vaccination, as such methods are now generally termed, and with this demonstration comes the well-founded hope that we are within sight of the goal so much hoped for, the discovery of a specific serum for the cure and prevention of tuberculosis. Indeed, we have already the news that two well-known bacteriologists have produced such a substance. While the details have not yet been made public, the names of these two men, Behring, of Germany, the discoverer of diphtheria antitoxin, and Marmorek, of the Pasteur Institute, in Paris, the discoverer of streptococcus antitoxin, are of such weight as to justify strong hope that they have achieved success. We may feel assured that marked progress has been made, to say the least.

I have not dwelt on the pathetic side of this question—the fearful loss of life and suffering entailed by a preventable disease. On this point I cannot do better than to quote a short editorial from a recent issue of *American Medicine* (March 28, 1903). While this deals with the city of New York, it is equally applicable to every city in the United States, the figures only needing modification.

The Tragedy of the Homeless and Friendless.

"In the year 1902, in the borough of Manhattan, there died of tuberculosis, chiefly in the various hospitals of the city, 1787 patients. Of these, 950 were "not known" at the addresses given; 456 gave no addresses; 275 gave the address of a lodging-house, and 106 gave an address outside of the city. It must be remembered that these deaths constituted only about one-seventh of all the deaths that took place. Moreover, for every death there are, according to Dr. Farr, about two years of illness endured. When one thinks how much our happiness, even in health, depends upon home and love and friendship, and that in illness and death the blessedness of these things is vastly increased, and then when one realizes that there are so many thousands of the sick and dying in our cities utterly homeless and friendless, the pity of it all becomes indeed terrible. The tragedy of obviable disease and needless

death kindles our zeal to stop the spread of infection, to discover the means of preventing the suffering, and, when this is not possible, to surround the lonely sick and dying with the best medical skill, attention and kindness that is possible. The desolation of their appalling loneliness is often doubtless greater than that of their illness and oncoming death combined."

PHILADELPHIA, April 4, 1903.

ON ARTIFICIAL PRODUCTION OF CRYSTALLIZED DOMEYKITE, ALGODONITE, ARGENTODOMEYKITE AND STIBIODOMEYKITE.

(Plate V.)

BY GEORGE A. KOENIG.

(*Received June 1, 1903.*)

In a paper on mohawkite, domeykite and other copper arsenides of the Mohawk mine (*Zeitsch. f. Krystall.*, etc., Vol. xxxiv, 1 Heft), I mentioned some attempts made by me to obtain domeykite in measurable crystals by the action of arsenic vapors upon metallic copper. One experiment gave crystals, although not measurable, but further trials failed at the time, evidently through my inability to maintain the proper temperature by means of an Erlenmeyer combustion furnace. The range between the temperature at which the crystals form and that at which the crystals melt is a very narrow one. On the other hand the eagerness with which the copper absorbs the arsenic causes heat, and hence the difficulty in adding just the right quantity of thermal energy from the outside. It occurred to me to try an electric current as a source of heat. The very first trial gave most promising results. The experiments were taken up in November, 1900, and continued until March, 1901. The adjoining figure illustrates the simple apparatus which proved itself adequate to all requirements.

In watching the rapid growth of the crystals the similarity of the phenomenon with the development of an egg occurred to me, and I applied the name "incubator" to the apparatus, than which no other could be more expressive.

The incubator consists of a piece of combustion tubing (T), closed at one end. The length is unimportant since only about three inches of it are in actual use. I have varied the diameter from three-eighths to three-fourths inch with no apparent difference in the action. The crystals do not grow any larger in a large tube than in a small one. Around the tube is wound a very thin platinum wire (W), beginning at the closed end. In order to keep the coils separated I laid three strips of thin asbestos paper (E) lengthwise upon the glass and then began winding. The first turn returns to the start, a twist is made, and thus a well-fixed start is secured

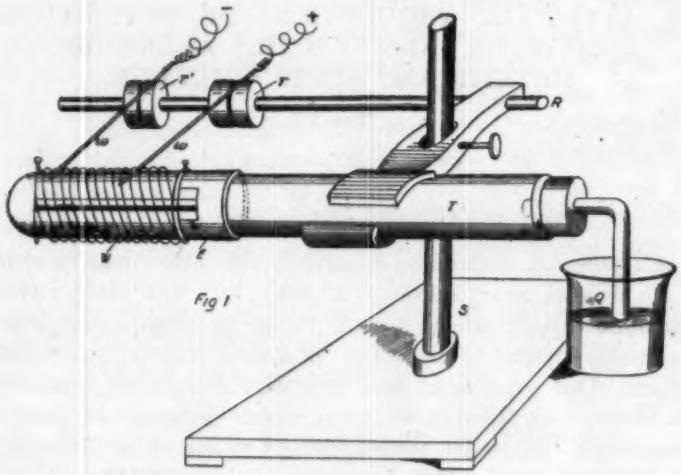

Fig 1

which will prevent the wire from slipping. The pitch of the thread will be governed by the maximum of heat desired. This will be variable with different metals and may be varied even for the same metal, as I have frequently done, the variation being between one-eighth and one-thirty-second of an inch. The last coil is secured in the same way as the first. Two inches of winding were mostly sufficient. Whenever the glass gets to full red heat the wire will fuse into it and will be broken in unwinding. To avoid this spoiling of the wire it would be the best thing to cover the whole glass surface with the asbestos sheet. But doing so would also prevent the observation of the phenomena occurring within. One might as well, or even preferably, use a porcelain tube. One would have to forego the great pleasure of seeing the so-called inanimate things

come to life, and one would make many more failures by either too much or too little heat. The wear and tear of the wire seems trifling when held against this loss. Being thus prepared the tube is ready to be charged.

At A (Fig. 2) I place from five to ten grams of resublimed arsenic, on top of this a loose plug of asbestos (P). In the first experiments I thought copper filings would be the best material to

Fig. 2.

act upon. These filings I poured on top of P, forming a column about one inch high, and secured this column by means of a second asbestos plug (P^1). Such an arrangement of parts promised to restrain the arsenic vapors from passing by the copper without action. It proved an unnecessary precaution, as the copper acts toward that vapor as a sponge toward water. Coarse turnings were tried instead of filings, and later solid copper bars with even better results than the filings had given. Similarly the close proximity of the copper to the plug P was found objectionable and, therefore, in all the later experiments the tube was placed, after charging the arsenic and inserting P, in a horizontal position by means of a clamp at the open end. Then the metal pieces to be acted upon were shoved into the desired distance from the plug, a loose asbestos plug next to the metal to avoid air currents, and finally a stopper holding a narrow glass tube, bent at right angles, was inserted into the open end. The glass tube was then made to dip under mercury and thus expansion of the air made possible, without danger of air entering. Whatever oxygen was in the tube made As_2O_3, which was always found as a ring sublimate behind the metal. Fig. 1 shows the outside of the tube, clamped to the stand S. The stout contact wires, w, w^1, were found very serviceable. By their use the field of high temperature may be enlarged or restricted as well as shifted. These wires are simply laid upon the coil wire. Their position must not be shifted or altered without switching off the current; the thin wire will melt in the moment when the contact is broken. I spoiled considerable wire in this way, besides the time consumed in rewinding is quite an item. A suitable, easily changeable resistance to modify the tone of the

thermic energy is made part of the circuit. A water resistance answers very well if a Mariotte's bottle be provided to keep the water level, and if the one wire be fastened to a swivel; the latter arrangement permits a quick and easy modification to $\frac{1}{1000}$ amps. In my work with the incubator a drum resistance coil with roller contact was used. The apparatus was placed into a dark room in which the faintest glow could be seen and thus the lower limit of temperature was probably 450° C., with the upper limit of C. 500° to 700°. The most satisfactory range for domeykite is about 600° C.

Aims of the Investigation.

At the start the aim was not so much the mere production of domeykite crystals, as the demonstration that nickel and cobalt might replace copper in the molecule without changing the symmetry, in other words to establish the isomorphous character of domeykite and mohawkite. This original scope became at once wider, when the results showed the ease with which domeykite was formed in good crystals. The action of arsenic upon iron, lead, silver, cobalt, nickel was included and equally satisfactory results were fondly hoped for.

A still farther circle could be described by drawing in antimony since silver was known to unite with antimony as Ag_3S_4. The hopes were not realized. Under other conditions perhaps better results may be obtained, at least in some cases. I am referring here to the action in vacuo. Up to this time I have not tried the vacuum, so much other work is constantly crowding in. I will not pre-empt work in this line and shall gladly see any colleague step in to take up this undoubtedly highly interesting work.

1. Action of Arsenic Vapors upon Copper in the Incubator —Domeykite.

a. Coarse copper turnings were placed in the tube (C. Fig. 2) so that about three-fourths inch of free space were left between the copper and the asbestos plug P, and the contact wires were so placed that the evaporation of the arsenic was fairly rapid, whilst the temperature of copper remained near the lower limit of say 500° C. Soon one saw shooting out from the copper very thin, brilliant leaves. The direction of growth was parallel with the tube's axis. The growth keeps up until the entire free space is filled with the bright crystal aggregate. The latter looks much like sublimed arsenic, and that I

thought it to be until the analysis showed it to contain 72.9 per cent. of copper. The crystals even penetrated into the asbestos, and from this very extremity the material for the analysis was taken. This experiment was carried on from 8 A.M., January 11, 1900, for forty hours. Here was a phenomenon of molecular or ionic activity without parallel; at least to me extraordinary, for I had not seen any record of a similar observation. It is not difficult to understand the building up of crystals from a medium which contains the molecules in the liquid or gaseous state. But what I observed here implied a very different condition of things. Not even the skyward growth of a tree, which somewhat resembles this stretching out of the domeykite toward the supply of arsenic, is comparable. For the cells draw their nourishment from the liquid sap and the gaseous air. The growing may happen from the root by pushing or by growing at the front. In the latter case the copper ions must be supposed to be going like the ions under the direction of a current, but going in the solid condition, and this is the point at which the imagination recoils. Either alternative rests upon a push or a draw impulse. The present experiment would seem to point toward a push from the root as the cause, that is to say to a mobility of the copper arsenide molecule Cu_3As. In Fig. 3 is represented one of the results of a later experiment, which gives support to the notion that the copper ions are moving and not the molecule Cu_3As. Here C is a piece of copper turning. On a slender stylus S sits the large domeykite crystal D (the tabular type, three millim. in diameter). The crystal is incomplete on one side. From it leads a second stylus S^1, and upon this another somewhat incomplete crystal of domeykite D has been growing. All the material for the crystals must have come through the stylus S. Instead of all the *material*, I should say more correctly all the copper. The stylus habit for the crystallization is very common; Fig. 3 merely represents an unusually fine specimen of this habit. Looking at the phenomenon of molecular mobility in the solid state merely as a physico-chemical process, aside from crystallization, I can see an analogous occurrence in the so-called cementation process of steel or case-hardening process. In this process a bar of soft iron is exposed to red heat in a packing of solid charcoal, and becomes gradually converted into carbid Fe_4C to the very innermost parts. It would seem that the solid carbon ions become mobilized, passing from one group of iron ions to the next until

chemical saturation has been reached. To my knowledge, however, no experiments have been put on record which absolutely precluded the coaction of gasified carbon as CO; I mean that the experiments were not carried on in perfectly air-tight vessels. Yet, granted even that the solid carbon travels by exchange through a bar of iron, the phenomenon is not quite correlated to our problem. For if the two were similar then the arsensic would have to penetrate to the core of the copper chip without altering practically its original shape. But in the specimen Fig. 3 the copper chip C is perfectly bright metallic copper, even immediately under the stylus S. Furthermore all the other metals behaved toward arsenic vapors as iron toward carbon: the arsenic penetrates

Fig 3

Fig. 4

and crystals do not shoot forth. Copper possesses, therefore, a *unique ionic mobility*. Since copper stands at the head as a conductor of both heat and electricity, may not this be due to that mobility of the ions?

b. If a copper chip be placed into the incubator and both resistance and contact wires be so adjusted that very little arsenic volatilizes, and that the copper is just below glowing heat, that is dark in a perfectly dark room, then the domeykite crystals arise from the copper as very thin tabular individuals, often of perfect hexagonal outline. Many of the crystals are only fractional (Fig. 4), and in this case look like bristles or spines, always at right angles to the surface, or if the latter be curved then the bristles will be in radial position. At first a few scattered crystals will come out, always nearest to the supply of arsenic, but later the entire surface will become covered with bristles. Under these conditions large

and full-faced crystals were never obtained. The largest crystals of the tabular habitus 4–5 millim. with prismatic and pyramidal faces well developed, but striated, so that they did not serve for measurements, were grown in a twenty-four-hour experiment. The crystals are fast to the asbestos of the plug P.

c. Experiment made January 14, 1901.—A piece of one-fourth inch copper wire two and one-half inches long was wrapped at one end with asbestos cord so as to form a plug which would support the wire within the incubator in a central position, thus giving a chance for free growth in all directions. At the end of fourteen hours the wire had been modified as shown in Fig. 5. The result was unexpected, probably owing to the change of current in the early morning, when the dynamo current had replaced the storage battery and the temperature had risen beyond the intended point.

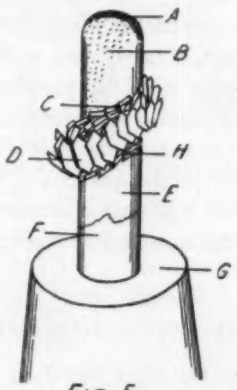

Fig 5

It is, however, all the more instructive, although a failure of the intention. Exceptionally large and fine crystals were expected to form by the arrangement, hence the failure. Instead seven distinct zones appeared, each telling a different story. Zone 1st (*a*). The end of the wire nearest to the asbestos plug and the arsenic and in the centre of the heated field is completely fused, showing a lead-gray color and dull compared to its neighbor. The end is deeply converted into arsenide and this has been fused. Zone 2d (*b*). Bright gray of the color of antimony, a jumble of crystalline faces, but no crystals, has been partly fused. Zone 3d (*c*). A narrow strip of small but well-formed crystals, which belong to

thick tabular type, has not been fused. Zone 4th (*d*). A collar of bristling hexagonal plates, some with prismatic and pyramidal faces, but withal belonging to the thin type. This collar of crystals looks jet-black, the contrast with the bright gray both striking and beautiful. In different light the crystals always appear black, only in reflected light the color is gray. This zone marks the minimum of temperature at which combination of copper and arsenic takes place. Zone 5th (*h*). Is very narrow and dull gray; it reveals miniature crystals of the thin type. Zone 6th (*l*). Shows the beautiful pale red color of pure copper. Evidently arsenic vapors surrounded this part of the wire; the temperature sufficed to let this arsenic combine with the oxygen of the surface, and thus give the latter the pure copper color, the peroxyd subliming. Next to this we find the wire with the usual red color due to a thin film of cuprous oxide.

d. A piece of quartz two inches long and just wide enough to go into my largest combustion tube, that is three-fourths inch, had a number of native copper crystals, pseudomorphous after quartz. This specimen was incubated. A growth of thick tabular domeykite crystals formed all over the one side of the quartz. The artificial nature is disguised by the quartz and the epidote in the association to such an extent that any mineralogist would take it as a thoroughly natural production and hence a most unique specimen.

2. Action of Arsenic Vapors upon Alloys of Copper, Nickel and Cobalt—Mohawkite, Keweenawite.

An alloy was made of the three metals in about the same proportion in which they are found in the natural mohawkite, that is

Cu	= 74
Ni	= 21
Co	= 5
	100

The alloy was cast into a bar one-fourth inch wide, and parts of this bar were successively exposed in the incubator under different conditions of temperature, of rapid or slow evaporation of arsenic.

First Experiment, December 18, 1900.—The alloy is converted into filings and these are put directly against the plug P in the

manner as described under copper, but the filings only occupied the lower half of the tube. Upon the upper flat surface crystals form of the thick tabular type, the first pyramid prevailing over the basal plane. The crystals are coherent laterally, crustlike, over a loose aggregate of bright, light gray crystalline matter with indistinct faces. At the time I thought these two materials were alike. But recently, on re-examination, it is seen that whilst the crystals have become much tarnished, the gray material has not changed at all. The crystal layer was detached as much as possible from the loose substance, for the analysis, but it was not possible to do this thoroughly.

The analysis of the crystals gave (0.216 gram):

Cu = 66.37	: 63	= 1.0524	1.0939
(Ni + Co) = 2.43	: 58.6	= 0.0415	
As = 30.90	: 75	=	0.4120
99.70			

Ratio:

$$(CuNi\ Co) : As = 2.655 : 1.000$$

The analysis of the gray loose material gave (0.2325 gram):

Cu = 44.30	: 63	= 0.7032	
Ni = 12.54	: 58.6	= 0.2822	0.9854
Co = 4.00			
As = 39.25	: 75	=	0.5230
100.09			

Ratio:

$$(CuNi\ Co) : As = 1.88 : 1.00 = 2 : 1$$

This then is typical Keweenawite, described recently by me (*Amer. Journ. Sci.*, Vol. xiv, December, 1902) as found at the Mohawk mine. The non-tarnishing quality is inherent also in the natural mineral, as mentioned *l. c.* The crystals on the other hand are mohawkite; the excess of arsenic making the ratio 2.655 : 1 instead of 3 : 1 is explained by the impossibility of separating the crystals from the adhering keweenawite.

Experiment of December 24, 1901.—Instead of filings, two fragments of the alloy were exposed in the incubator for twenty-seven hours. Hexagonal plates, very thin, formed upon a crust of gray material strongly crystalline. The plates stood at right angles to the surface and could be brushed off with small camel's-hair brush.

The analysis with 0.0867 gram of the absolutely pure crystals gave :

Cu = 69.31 : 63	= 1.1002	1.1463
(Ni + Co) = 2.70 : 58.6	= 0.0461	
As = 28.12 : 75	=	0.3750
100.13		

Ratio :

(CuNi Co) : As = 3.06 : 1.00 = mohawkite

Both experiments show conclusively that nickel and cobalt will enter the crystals without changing the hexagonal symmetry; that domeykite and mohawkite are indeed isomorphous. At the same time the interesting fact is to be dealt with that nickel and cobalt do not pass into the arsenide with the copper in the ratio in which the alloy exposes them to the action of the arsenic vapors. That in fact the ionic mobility of nickel and cobalt is only approximately one-sixth that of the copper. For in the alloy the ratio of copper to nickel and cobalt is nearly 4 : 1, whilst in the crystals it is 25 : 1. The highest percentage of Ni + Co furnished for mohawkite was 4.51, but the analysis was otherwise unsatisfactory.

3. Action of Arsenic Vapors upon Nickel.

Two cakes of nickel were exposed in the incubator for twenty-four hours. No crystals could be obtained, not even of the most imperfect type. A brittle material formed as a thin crust of a dull gray color. It was not analyzed. The action upon cobalt was similar. The ionic mobility of these metals under these conditions seems to be near zero. We may infer that in the previous experiments Ni and Co were moved by infection from the copper's ionic vigor.

4. Action of Arsenic Vapors upon an Alloy of Copper with Silver—Argentodomeykite.

The metals were melted together in the proportion 9 : 1. The alloy was cast into a bar and fragments of this were exposed in the incubator.

Experiment of January 22, 23, 1901.—The material for action is a solid piece of the bar about 15 x 25 millimeters. The crystals grew out of this alloy towards the arsenic as rapidly as out of pure copper. They are of the tabular variety, medium thickness. The

pyramidal faces are hollow (see Dr. Wright's Fig. 3). The dark gray crystals are surrounded at the base by a fringe of *silver-white crystals* of the thin plate type. It happened that the exposure began about 9 A.M. on a Saturday morning. At 6 P.M. the crop of crystals had developed finely, but I hoped that they would become extra large by longer exposure. On Sunday I was prevented from going to the laboratory, and on my arrival on Monday I found the incubator barely warm to the touch. The storage battery had run down over Sunday, and to this accident we owe this beautiful and interesting preparation which I now hold in my hand. On seeing the silver-white crystals I thought, first thing, that I was beholding a silver arsenide, but the analysis proved my judgment to have been in error.

The composition is

$$\left.\begin{array}{lll} Cu = 80.49 : & 63 & = 1.2773 \\ Ag = \ 2.60 : & 107.6 & = 0.0242 \end{array}\right\} \ 1.3015$$
$$As = 16.93 : \ 75 \ = \qquad 0.2257$$

Hence the ratio:

$$(CuAg) : As = 5.77 : 1 = 6 : 1$$

This substance then is *argentoalgodonite.*

The dark gray crystals have the composition:

$$\begin{array}{rl} Cu = & 70.40 \\ Ag = & \ 2.30 \\ \text{(By difference) } As = & 27.30 \\ \hline & 100.00 \end{array}$$

This is the ratio:

$$(CuAg) : As = 3 : 1$$

or what I will name *argentodomeykite,* which we shall, sooner or later, find undoubtedly as a natural mineral. But how about the algodonite? In no other experiment was it observed. Since the form of the crystals is identical with the argentodomeykite, I venture to assert that the algodonite is pseudomorphous after the domeykite, and owes its existence to a retrogressive process in this way: when the temperature was slowly going down (with the current from the battery) the arsenical atmosphere became more and more rarefied with the greed of the metallic copper still active. Hence the copper began to draw the arsenic from the nearest

domeykite crystals and the latter became algodonite. Since the algodonite is only found at the base, near the copper, the explanation seems to me plausible enough.

Experiment of January 5, 6, 1901.—A piece of silver was exposed in the incubator. It was supposed to be quite pure; but, as will be seen from the analysis, it contained several per cent. of copper. For several hours no action appeared to take place, behavior being similar to nickel. Then the edges began to round and towards evening the piece of alloy went into complete fusion at a temperature certainly not above 450° C. Seen by candle-light, through the glass tube, the material had the appearance of a large drop of mercury, being seemingly very mobile. The following morning (with the weaker current) it was found solidified, but no sign of crystals. The substance broke readily under the hammer; the fracture shows cleavage faces and a light gray color.

The analysis gave (0.4795 gram):

		Atoms.	
Ag =	74.32	0.688	0.763
Cu =	4.72	0.075	
(Difference) As =	20.96		0.273
	100.00		

Ratio:

$$(AgCu) : As = 2.79 : 1.00$$

There is, therefore, a molecule Ag_3As with a tendency, however, to pass into Ag_4As; some of the latter is shown in the ratio $\frac{3}{4}$, instead of 3, which corresponds exactly to 4 Ag_4As + Ag_3As.

Experiment of January 21, 1901.—Piece of alloy (1 copper, 1 silver) exposed twenty-one hours. A beautiful growth of thick tabular crystals, which sit up on a gray crystalline layer, under which appears a thin zone, silver-white in color, 1/2 millimeters thick; then comes copper-red. The growth is entirely in the axis of the piece and tube towards the arsenic.

The analysis of the crystals gave:

Cu =	62.02	0.9844	1.0882
Ag =	11.21	0.1038	
As =	26.77		0.3569
	100.00		

Ratio:

$$(CuAg) : As = 3.05 : 1.00$$

The silver-white zone under the crystals demonstrates to the eye the difference in the ionic mobility of copper and silver. One sees how the copper is drawn away from the silver. It would be of interest to know whether the outermost crystals carry less silver than those nearest the metallic base, but as this gain of knowledge would also involve a destruction of the specimen I abstained, satisfied with the average result as exhibited in the above analysis.

Experiment of February 24, 1901.—An alloy of 1 copper with 1 silver was made and a piece weighing about 5 grams was exposed in the incubator for fourteen hours (over night). The front and upper surface of the ingot was found covered with crystals. They are not good, but they show distinctly the habitus of the thick tabular domeykite. There is no tendency to rise; the silver is evidently as little mobile as the nickel and acts depressingly upon the activity of the copper. The crystals are laterally grown together, forming a strongly cohering crust, which cracks off with the hammer blow.

Analysis of the crust gave (0.3057 gram):

		Atoms.	
	Cu = 55.87	= 0.887	1.026
	Ag = 15.01	= 0.139	
(By difference)	As = 29.12	=	0.388
	100.00		

Ratio:

$$(CuAg) : As = 2.65 : 1.00$$

This corresponds to a mixture of 5 $(CuAg)_3As$ with 3 $(CuAg)_2As$. The tendency is always rather for the building up of Cu_2As than of Cu_3.

Experiment of February 28, 1901.—A piece of alloy 1 Cu + 1 Ag exposed in incubator for two days and nights at very low temperature. The end reaching towards the arsenic showed a fused, bluish-gray, apparently homogeneous material. At the opposite end are small crystals with bright faces. Habitus: steep hexagonal pyramid with striated sides, capped by the normal or fundamental pyramid.

Analysis with 0.3412 gram gave:

		Atoms.	
	Cu = 40 94	= 0.650	0.989
	4 Ag = 36.62	= 0.339	
(By difference)	As = 22.44	=	0.2992
	100-00		

Ratio:

$$(CuAg) : As = 3.3 : 1.00$$

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This is the single instance in which the metal exceeds the $\frac{3}{1}$ ratio, if we exclude the instance of the algodonite. I venture to explain it by a similar process of retrogression, or, perhaps, better, by ingression of the still very mobile metal ions into the molecule $\frac{3}{1}$ after the arsenic vapor had become too rarefied for addition from the outside, as the temperature was sinking—*i.e.*, the current going down. All the experiments with the copper-silver alloy prove: 1. Silver and copper together replace one another isomorphously in the molecule $\frac{3}{1}$. 2. The representation is 63 Cu by 107.6 Ag—*i.e.*, divalent copper with monovalent silver. 3. There is a molecule, Ag_3As, whose melting-point is below the temperature of formation; hence not crystallizable in the incubator. 4. Higher temperature tends to forming Ag_3As, same as Cu_3As.

5. The Action of Arsenic Vapors upon an Alloy of Copper and Antimony—Stibiodomeykite.

If copper and antimony were melted together in such proportion as Cu_6Sb, which corresponds nearly to copper 3 parts, antimony 1 part, in percentage Cu = 75.6, Sb = 24.4, and such an alloy were to be exposed at the proper temperature to the arsenic vapors, one might be justified in supposing that by simple addition of one atom of As we would get

$$Cu_6Sb + As = 2\ Cu_3(SbAs)$$

if there were a tendency in the elements to form such a combination; or if the molecule Cu_3Sb(Cu = 66 Sb = 34) were exposed, then one As might couple together two molecules of Cu_3Sb.

Experiment of February 1, 2, 3, 1901.—The alloy Cu_3Sb was exposed for three days and nights at very low temperature. In the absolutely dark room the wire coil showed dull redness. Very large tabular crystals form, drawn in the axis of the tube forward the arsenic. The crystals have the color and habitus of domeykite. Their composition is:

	Cu =	69.34
(0.1422 gram)	Sb =	1.26
(By difference)	As =	29.40
		100.00

Ratio:

$$Cu : (AsSb) = 2.76 : 1.00$$

The analysis reveals two points: 1. Arsenic does not add itself to a ready-formed molecule Cu_3Sb. The same preferential attraction towards copper comes into play as in the case of the metallic constituents of copper alloys. The ionic mobility of antimony is low; at any rate, at the low temperature in use during this experiment. 2. The ratio indicates that antimony is probably merely mechanically carried along so long as copper is at hand for the arsenic; for if antimony be considered out of the molecule the ratio will be $Cu : As = 2.82 : 1.00$. But even this is unsatisfactory for a crystallized body with no mechanical admixture likely, for the crystals were all separate and large enough to be fully scrutinized.

For more light I went to examine into the material directly under and back of the large crystals. This material is loose, in small loose grains of angular habitus, not scaly at all, as the large crystals. Habitus quite unlike that of the domeykite; color darker gray. The analysis of this material (0.0570 gram) gives:

$CuO = 0.0393$	$Cu = 55.44$	: 63 =		0.08800
$Sb_2S_3 = 0.0028$	$Sb = 3.51$	: 122 = 0.0287	}	0.571
$As_2S_3 = 0.0480$	$As = 40.66$	: 75 = 0.5421	}	
	99.61			

Ratio:

$$Cu : (AsSb) = 880 : 571 = 3.08 : 2$$

As the copper becomes scarce, the arsenic being still plentiful, this new $3/2$ molecule forms. In spite of the superabundance of antimony, the selection of copper continues. With nickel we saw in similar conditions the forming of $2/1$ molecule. The affinity for antimony is quite low, and yet it is probably the influence of the latter through which $3/2$ and not $2/1$ are brought into being. The excess of arsenic in the large crystals accounts for itself by the presence of this $3/2$ molecule under the influence of antimony.

Experiment of February 4, 1901.—The same alloy Cu_3Sb was exposed for thirty-six hours at a higher temperature, about 550° C. Two products were obtained. Forward, towards the arsenic, a lustrous gray mass, apparently of fused crystals. The outermost part of this mass was broken off, revealing a hollow center, an inner layer of dark-gray mass, an outer layer of lighter color. Could not separate the two. Let this be material (a'). The second substance

is composed of crystals of the domeykite habitus, thin and thick tabular; all but very few show rounded edges—that is, incipient fusion. A part of the crystals was removed. Material (*a*).

Analysis of *a* (0.4801 gram); many individual plates, others grown together.

Cu — 69.79 :	63 —		0.1078
As — 20.32 :	75 — 0.2709	}	0.3509
Sb — 9.74 :	122 — 0.0800	}	
99.85			

Ratio:

$$Cu : (AsSb) = 3.11 : 1.00$$

These crystals are thus proved to be *stibiodomeykite*. It also follows that higher temperature increases the ionic mobility of the antimony.

The analysis of the material (*a'*) (0.4823 gram) gives:

Cu = 45.10 :	63 =		0.7158
Sb = 36.83 :	122 = 0.3019	}	0.5428
As = 18.07 :	75 = 0.2409	}	
100.00			

Ratio:

$$Cu : (SbAs) = 1.32 : 1.00 = 4 : 3$$

I take this to mean a mixture in which the outer crust is Cu (SbAs), whilst the inner layer is $Cu_4(SbAs)_2$; $1/1 + 3/2 = 4/3$.

Experiment of February 7.—A fragment of the alloy Cu_3Sb was again exposed with the intention of keeping the temperature, if possible, below that of the one preceding, and yet higher than in the first experiment. The exposure was forty hours. It must be remembered that owing to the local conditions a perfectly uniform temperature could not be maintained unless the ammeter were under steady observation—an impossible or at any rate too difficult a proposition. Hence the temperature would steadily decrease, whilst the potential sank from 120 to 110 volts and would rise (during the night) to 125 volts, when in the forenoon the dynamo was coupled to the storage battery.

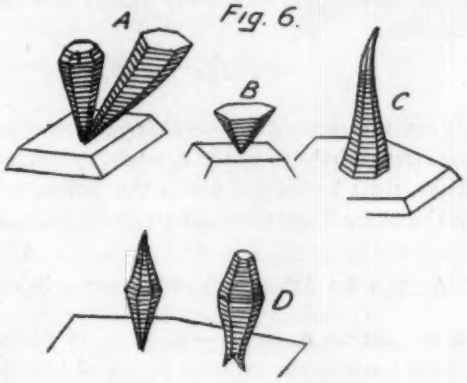
The original alloy was found covered with three products:

1. A fine granular crust.
2. Over this a peculiar sort of crystals not showing any one of

the habitus of domeykite. These crystals are all fused together laterally; the faces are rough like the leaves of reeds. They are not measurable.

3. On these faces rise curious pyramidal forms as shown in Fig. 6. The crystals are slender and small. Their faces are bent and very uneven from the alternation of pyramid and prism. The acute pyramid predominates, but apex is closed by the normal pyramid

Fig. 6.



(see Dr. Wright). Some of the forms, as at *a.a.*, resemble minute cup corals; others, as at *b.d.*, imitate a club, whilst *c.c.* may be likened to a church steeple.

ad. 1 and 2. Crust and crystals cannot be separated.

Analysis gives (0.0532 gram):

Cu	= 67.74 :	63	= 1.0752
Sb	= 1.00 :	122	= 0.0082
(Difference) As	= 31.26 :	75	= 0.4168
	100.00		

Hence ratio:

$$Cu : (AsSb) = 2.52 : 1 = 5 : 2$$

Corresponding to a molecular mixture:

$$3'/1 + 2/1 = 5'/2$$

ad. 3. The crystals are so small that the whole of them would not make 0.1 gram. The sacrifice of any of them came hard. 3.97 milligrams weighed on a button balance, which is accurate to

0.005 mg., was dissolved in HNO_3 and evaporated to dryness. The dry mass dissolves in water, to which a drop of dilute H_2SO_4 has been added. Solution is without opalescence. Hence *antimony* can only be present in traces. Then 2.78 mg. of fine copper wire was dissolved in HNO_3, this being just seventy per cent. of the arsenide. Both solutions made ammoniacal were compared in proper dilution of 50 cc. on the colorimeter. The color of the solution from the pure copper is slightly lighter and by adjustment brings the percentage

$$Cu = 72$$

The crystals are thus proven to be *domeykite* and not stibiodomeykite. The strange habitus of the crystals, so unlike that of the prevalent habitus, must be looked for in the influence of the antimony, though the latter does not itself enter the composition.

6. Action of Arsenic Vapors upon Zinc.

Experiment of March 2, 1901.—A piece of chemically pure zinc, broken from a stick, was exposed for twenty hours. The surface is covered by a crust which is developed into mamillary groups, somewhat like psilomelane. The crust detaches itself by a blow from the hammer and breaks into flaky pieces resembling graphite.

Analysis gives (0.222 gram):

$$ZnO = 0.1720 = 0.1381\ Zn$$

Hence

$$Zn = 62.20$$
$$\text{(By difference)}\ As = 37.80$$
$$100.00$$

$$Zn : As = 959 : 504 = 1.902 : 1$$

$$Zn_2As$$

Zinc acts toward arsenic vapors like nickel; the ratio 2 / 1 seems to be the normal.

7. Action of Arsenic Vapors upon Lead.

The lead melts. Exposure for twenty hours. Product is still

malleable to some extent, but breaks off short when nicked with the chisel and then bent. Looks homogeneous.

Analysis gave:

Pb =	96.10
As =	3.75
	99.85

$$Pb : As = 0.4637 : 0.050 = 9.27 : 1$$

The ratio is that of whitneyite. The ionic mobility is small.

MICHIGAN COLLEGE OF MINES, May, 1903.

CRYSTALLOGRAPHIC PROPERTIES.

BY FRED EUGENE WRIGHT.

The following group of artificial minerals, which Dr. Koenig has kindly intrusted to me for crystallographic investigation, is characterized by high metallic luster, tin-white to steel-gray and even black color, conchoidal fracture and hardness: 3–4. The crystals obtained are all small and rarely exceed a millimeter in length. The character and quality of the crystal faces is not uniform for the whole group. Those of domeykite are usually sharp, well formed and furnished single reflection signals on the goniometer, whereby a fairly exact determination of its elements could be obtained. The crystals of the remaining minerals are far less perfect, their uneven undulating faces evincing such indistinct, manifold reflexion signals on the goniometer that an accurate determination of their elements was impossible.

The crystals were measured on a Goldschmidt's two-circled goniometer (model 1901), with attachment for observing small, weak faces and an electric arc goniometer lamp.[1]

[1] The electric goniometer lamp (Fig. A) consists of a box (*a*) made of Russian sheet iron, lined with asbestos cardboard, and of an electric lamp (*b*). The back of the box (*a*) is left open to allow the insertion of the electric lamp—a small black movable curtain serving to shut off all false light, which might disturb in measuring. The mirror (*d*) and cap (*e*) are used to light the verniers and were taken bodily from a Goldschmidt's Auer burner gas goniometer lamp (see *Zeitschrift für Krystallographie*, Bd. xxiii, 1894, p. 149. V. Goldschmidt. Eine neue Goniometer-lampe). The electric lamp (*b*) is the No. 10, hand feed, of J. B. Colt & Co., Chicago, Ill. (price, $10), together with an adjustable rheostat (seven to eighteen ampères, $13). By means of the latter the intensity

Domeykite.

Twelve domeykite crystals were measured, all of which indicated the holohedral division of the hexagonal system with the following observed forms:

Letter:		*c*	*b*	*a*	*s*	*v*	*p*	*x*
Symbol	Bravais	0001	$10\bar{1}0$	$11\bar{2}0$	$20\bar{2}3$	$10\bar{1}1$	$20\bar{2}1$	$11\bar{2}2$
	Goldschmidt	0	∞ 0	∞	$\frac{3}{2}$ 0	1 0	2 0	$\frac{1}{2}$

Also two uncertain forms ? $\frac{1}{6}$ 0 ($10\bar{1}6$), which occurred only once

---

of the light may be regulated. An ammeter may be used, but is hardly necessary. In the slits in the tube (*f*) two small colored (blue and green) pieces of glass are placed, which cut down the intensity of the light and impart to it a color restful to the eye. In case very bright light is needed one of the glass plates

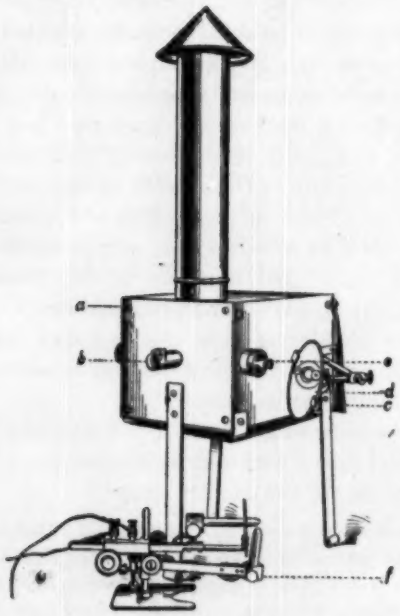


Fig. A.

may be removed. The carbons are observed through a round piece of glass fitted in the cap (*e*). The electric arc goniometer lamp is especially adapted for the measurement of etch figures and minute crystal faces, but serves equally well for ordinary measurements as the light intensity may be regulated and cut down at will.

as a sharp, perhaps vicinal face on crystal No. 4; and ? $\frac{1}{2}$ 1 ($12\bar{3}2$), observed once as a small rounded face (crystal No. 3).

Element: $p_0 = 1.0259 \pm 0.0006$
$a : c_{10} = 1 : 0.8885$ [1]
$a : c_1 = 1 : 1.539$

The element p_0 was calculated from the mean of the angles of 27 sharp, single reflecting pyramidal faces of the measured crystals, no attempt being made to separate the different types of crystal habit. The form *v*, 10 furnished 12 of these faces ($\varphi = 30° 00'$, $\rho = 45° 44'$, possible error ± 1′), the form *p*, 20, 11 faces ($\varphi = 30° 00'$, $\rho = 64° 01'$, possible error ± 3′), and the form *z*, $\frac{2}{3}$ 0, 4 faces ($= 30° 00'$, $\rho = 34° 23'$, possible error ± 1′).

Table of Angles.[2]

c—1′539	lg c—018721	lg a_0—005135	lg p_0—001112	a_0—1′1255	p_0—1′0259	(G_1)

No.	*Letter*	*Symbol*	*Bravais*	ϕ	ρ	ξ_0	η_0	ξ	η	x (*Prisms*) ($x : y$)	y	d — $tg\ \rho$
1	*c*	0	0 0 0 1	—	0.00	0.00	0.00	0.00	0.00	0	0	0
2	? *a*	∞	1 1 $\bar{2}$ 0	30.00	90.00	90.00	90.00	30.00	60.00	0′.5 773	∞	∞
3	*b*	∞ 0	1 0 $\bar{1}$ 0	0.00	90.00	0.00	90.00	0.00	90.00	0	∞	∞
4	*z*	$\frac{2}{3}$ 0	2 0 $\bar{2}$ 3	0.00	34.23	0.00	34.23	0.00	34.23	0	0′.6840	0′.6840
5	*v*	1 0	1 0 $\bar{1}$ 1	0.00	45.44	0.00	45.44	0.00	45.44	0	1′.0259	1′.0259
6	*p*	2 0	2 0 $\bar{2}$ 1	0.00	64.01	0.00	64.01	0.00	64.01	0	2′.0518	2′.0518
7	? *x*	$\frac{1}{2}$	1 1 $\bar{2}$ 2	30.00	41.37	23.57	37.34	19.23	35.06	0′.4443	0′.7730	0′.8885

Description of the Individual Forms.

1. The form *c*, 0 (0001) was absent on only one crystal (No. 9, Fig. 4). It has sharp hexagonal outline, splendent metallic luster and is usually perfectly flat, except in the larger crystals where it is frequently uneven and undulating. If observed under a micro-

[1] $a : c_{10}$ denotes the axial relation of the pyramid 10 (10$\bar{1}$1) and $a : c_1$ those of the pyramid 1 (11$\bar{2}$1). See V. Goldschmidt, *Index der Krystallformen*, Vol. i, p. 35.

[2] Calculated according to scheme given in *Winkeltabellen*, von V. Goldschmidt.

scope lighted by auto-colimation the basal plane frequently appears covered with three systems of fine lines, cutting one another at an angle of 60° and running parallel to the outer edges of the crystal. The striæ are usually so fine that they are invisible to the naked eye and have no effect on the sharp reflexion signal from the face.

2. The form a, ∞ $(11\bar{2}0)$ is rare, occurring but once on one crystal, and then somewhat rounded. From the correct position of the reflexion signal, however, the character of the zone and relations

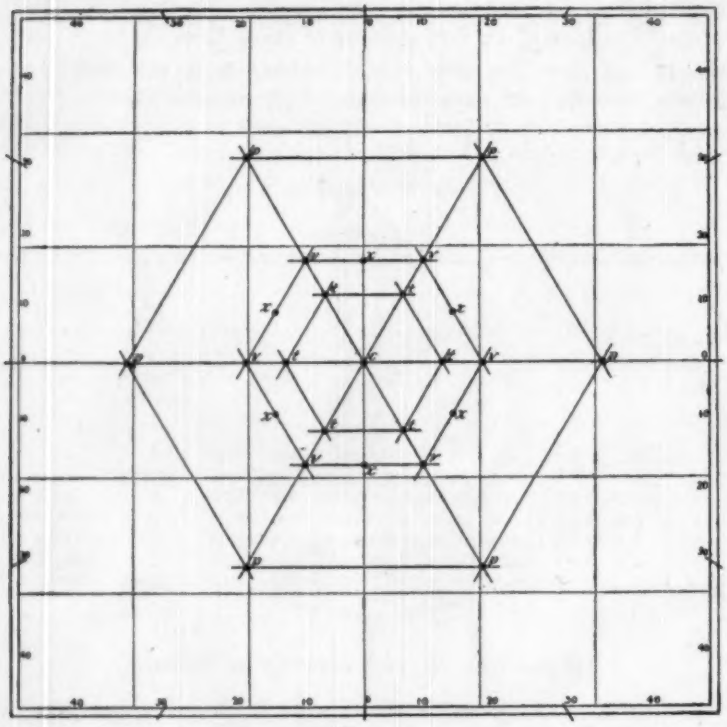


Fig. 1.

to the other faces, the form was considered probable. Its position on the crystal is given in Fig. 4.

3. The form b $(10\bar{1}0)$, ∞ o was observed on ten of the twelve measured crystals, often perfectly even and flat, at times, however, striated parallel to the basal edge—a phenomenon especially noticeable on the hollow skeleton-like crystals (Fig. 3), and due probably to the imperfect formation of the face.

The character of the three pyramidal faces *z*, *v*, *p*, is uniform and unvaried. Long narrow faces exhiting occasionally fine striæ parallel to the basal edge, particularly on the hollow crystals. The form *z*, $\frac{2}{3}$ o ($20\bar{2}3$) appeared on three of the measured crys-

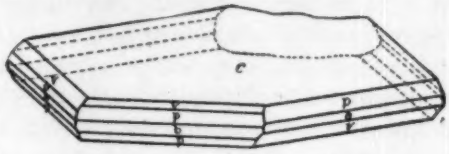


Fig. 2.

tals, *v*, 10 ($10\bar{1}1$) on ten, and the form *p*, 20 ($20\bar{2}1$) on ten and on one crystal as the only pyramid (Fig. 5).

The form *x*, $\frac{1}{2}$ ($11\bar{2}2$), like *a*, ∞ o, occurred but once and on the same crystal with the latter, as a small rounded face (Fig. 4).

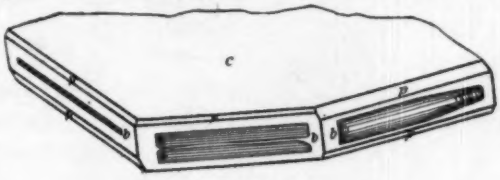


Fig. 3.

Its reflexion signal was approximately in its correct position. The form is considered probable.

Fig. 1 gives a gnomonic projection of all the observed forms on domeykite.

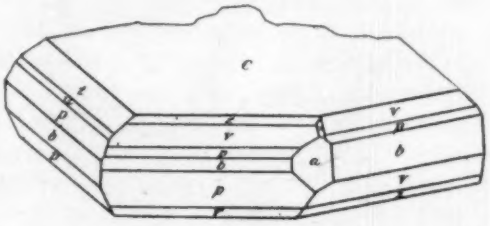


Fig. 4.

Types of Crystal Habit.—Fig. 2 (crystal No 1, dimensions 1.2 × 1.2 × 0.3 mm.) illustrates the first and most common type of domeykite crystals. Flat, thin tabular cystals with the forms o, ∞ o, 10, 20, the last three as narrow, sharp faces frequently striated horizontally. These artificial crystals are occa-

sionally hollow and resemble then Fig. 3 (crystal No. 8, 1.1 × 1.0 × 0.4 mm.). The central part of the prism faces is not filled out as yet, while the basal plane is perfectly flat, although in some cases a mere fragile paper-like film. The pyramid faces are usually present in the form of narrow strips. The hollow parts of the crystals seem to consist of a pile of innumerable thin plates piled one on top of the other, similar to the structure of a biotite crystal. The first type passes gradually into a thicker tabular one, in which the pyramid faces are more prominent. Fig. 4 (crystal No. 5, 0.9 × 0.9 × 0.5 mm.). In one case the steep pyramid p, 20,

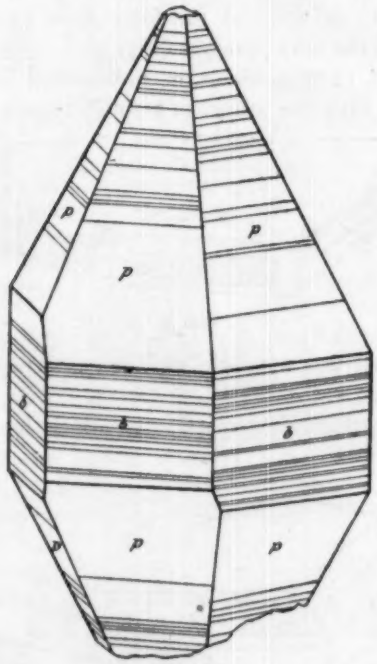


Fig. 5.

with b, ∞ o, were the only faces developed. Fig. 5 (crystal No. 9, 1 × 0.5 × 0.6 mm.). Fine horizontal striæ were then apparent on all faces of the crystal. Rounded transitional faces between v and c were noticed on one crystal.

Of the measured crystals No. 1 (with the observed forms c, v, p, b), No. 7 (with c, v, p, b), No. 10 (with c, v, p, b), No. 12 (with c, v,

p, *b*) belonged to the first type of crystal habit; No. 8 (with *c*, *p*, *b*) to the second; No. 2 (with *c*, *z*, *v*, *b*), No. 3 (with *c*, *v*, *p*, *b*), No. 4 (*c*, *v*, *b*, $\frac{1}{6}$, o (?)) No. 5 (*c*, *z*, *v*, *p*, *a*, *b*, *x*), No. 6 (*c*, *z*, *v*, *p*, *b*) and No. 11 (*c*, *v*, *p*) to the third, and No. 9 (with *p*, *b*) to the fourth.

Development of the Crystal Forms.—The only zone of any consequence present is that of the pyramid from the base to the prism. Considering the base and prism as primary forces the series reads *c*, *z*, *v*, *p*, *b* or o $\frac{2}{3}$ 1 2 ∞. This series is normal except for the second member $\frac{2}{3}$. The sense of this variation is not apparent. The primary forces have produced in the domeykite crystals the most common crystal faces. The simple dominant of the series *v*, 10, and the form *p*, 20, appear equally well developed, while the most highly differentiated form *z*, $\frac{2}{3}$ o occurs least frequently.

The crystals of domeykite tarnish easily to iridescence, and are then unfit for measurement. Luster of fresh crystals splendent metallic; color tin-white to steel-gray in reflected light, black in diffused light, often with a tinge of red. Fracture conchoidal, uneven. Brittle. Indications of a cleavage or parting after the base may result from the leafy texture mentioned above. Cleavage after the prism *a* (11$\bar{2}$o)) ∞ imperfect but distinctly noticeable. The specific gravity was left undetermined, as sufficient material for an accurate measurement was not available.

Etch Figures.

In these experiments the etch figures on the basal plane only were observed. This face is the largest and most perfect, and the one best adapted to reveal the crystallographic nature of the mineral. The other faces, moreover, occur only as narrow bands, frequently striated horizontally—two features detrimental to the formation of good etch figures.

In the process of etching, the minute domeykite crystals were placed in a small receptacle or holder made of finely woven platinum wire meshes, attached to which was a long handle of thicker wire, and then dipped into the acid, allowed to remain there a certain length of time, finally removed by means of the thick wire handle and plunged quickly into water. In this manner it was pos-

[1] Compare V. Goldschmidt, "Ueber Entwickelung der Krystallformen," *Zeitschrift für Krystallographie*, Bd. xxviii, p. 1–35, 419–451.

sible to measure the time of attack or exposition of the acid exactly to a second.

Etching acids used were NO_3H and HCl. The action of these two acids on the domeykite crystals is totally different. The nitric acid works energetically and causes a strong development of gas which keeps the submerged crystal in constant motion. The hydrochloric acid in contrast attacks the crystals very slowly (even when heated), causes no gas bubbles but becomes gradually colored yellow.

Nitric Acid.—With this acid the best results were obtained with a cold (15° C.) dilute solution of four parts concentrated nitric acid (70.6 %, sp. gr. = 1.426) and five parts water, with time of exposition 10″–20″. On one crystal unusually sharp etch figures were observed after an exposition of 13″. A long series of different concentrations were tried (from concentrated NO_3H down to 1 : 2 and lower). The times exposed varied from 10″ up to 120″. Nitric acid appears to etch most rapidly parallel to the outer edges of the crystal. The etch figures are very small, remarkably flat and shallow; exhibit generally sharp hexagonal outline, and grade especially on too long exposition or too concentrated acid into a hexagonal network of three systems of straight lines running parallel to the outer edges of the crystal. Compare the following figures:

Fig. 9	(dilution	4 : 5.	Time of exposition	30″.	Magnification	40 ×).
Fig. 10	"	4 : 5.	"	"	20″.	"	60 ×).
Fig. 11	"	4 : 5.	"	"	40″.	"	40 ×).
Fig. 12	"	3 : 4.	"	"	60″.	"	60 ×).

On one crystal, however, three-sided figures were observed, their slightly convex lines running parallel to the outer edges of the crystal. On several crystals one of the three systems of lines appeared in certain parts of the field to be less strongly developed than the remaining two sets, while in other parts of the field a second system was absent, etc. (Fig. 11). The rule seems to hold good in such cases that in the near vicinity of an outer edge that system of lines is poorly developed which runs parallel to the edge. The outer edge seems to have had a certain influence on the developme of the lines of the etch figures. Usually, however, all three sets of lines are equally well formed (Fig. 12). The etch figures are so small that they give no noticeable reflexion signals on the goniometer.

Hydrochloric Acid.—Hydrochloric acid attacks domeykite under

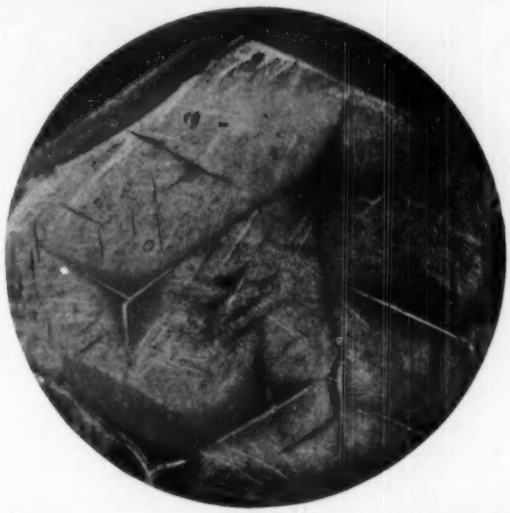


FIG. 9.

FIG. 10.

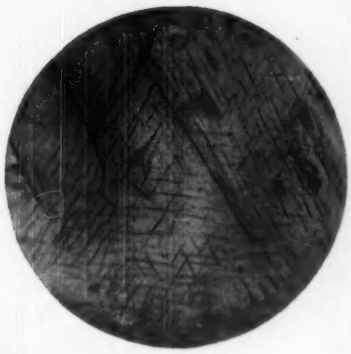


FIG. 12.

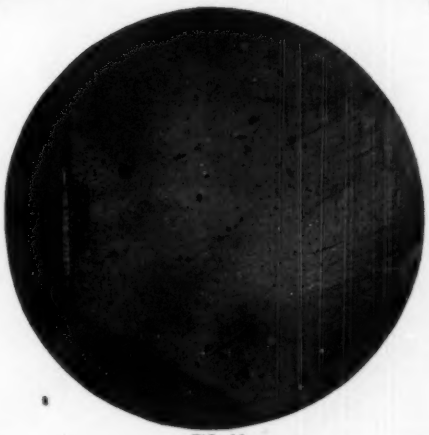


FIG. 11.

all conditions of concentration and temperature only very slightly. In one experiment with cold HCl (1 part concentrated HCl 30.5 %, sp. g. = 1.515 with 1 part water, time of exposition 7′), however, very small etch figures with sharp hexagonal outline were produced, not unlike those resulting from nitric acid. Their edges ran also parallel to the outer crystal edges. The absence of one set of parallel lines in the vicinity of that outer edge to which it was parallel was also observed on one crystal, etched with HCl. It is noteworthy that in this chemical process no noticeable gas bubbles are seen to escape.

Both the crystallographic measurements and the etch figures seem thus to prove the hexagonal nature of artificial domeykite crystals. On the following minerals, however: argentodomeykite, stibiodomeykite and mohawkite, the basal plane was so poorly developed that good, trustworthy etch figures could not be obtained. Their crystallographic system was deduced solely from the goniometric measurements.

In a recent article[1] on artificial domeykite crystals, Mr. Stevanovics considers the crystals examined by him to be orthorhombic, notwithstanding the hexagonal symmetry of his measurements, and bases his conclusions on the appearance of a cleavage after the macropinacoid, 100. A careful investigation by the present writer confirmed the cleavage noted above after three faces 60° apart. The cleavage seemed equally good after all three faces. In certain pieces cleavage fragments of perfect hexagonal outline (equilateral triangles) were produced. On the goniometer the angle between two such cleavage faces was found to be approximately 60°. The basal plane was uneven and did not permit an exact adjustment of the crystal.

The elements and forms described by Mr. Stevanovics were the following:

Orthorhombic: $a : b : c = 0.5771 : 1 : 1.026$

Forms:	*c*	*m*	*b*	*p*	*d*	*v*	*g*	*z*	*e*	*r*?	*t*?	*q*?
	001	110	010	111	021	112	011	113	023	043	041	0.5.12

with *t*, *r*, *q* rare and uncertain.

As hexagonal crystals these elements and forms become:

[1] *Zeitschr. f. Krystallographie*, Vol. xxxvii, pp. 245–246, 1903.

Element:		p_0 — 1.0206						
		$a : c_{10}$ — 1 : 0.8838						
		$a : c_1$ — 1 : 1.531						
Forms:	c	m, b	t (?)	d, p	g, v	r (?)	e, z	q (?)
Bravais.....	.0001	$10\bar{1}0$	$40\bar{4}1$	$20\bar{2}1$	$10\bar{1}1$	$40\bar{4}3$	$20\bar{2}3$	$50\bar{5}12$
Gdt.....	0	∞ 0	40	20	10	$\frac{4}{3}$	$\frac{2}{3}$ 0	$\frac{5}{12}$ 0

Argentodomeykite.

The crystals of the artificial argentodomeykite belong also to the holohedral division of the hexagonal system. Four crystals only were measured, each crystal exhibiting slightly different elements, due probably to a varying percentage of silver. For the form p, 20 of the several crystals

The angle $\rho = 65° 14' \pm 29'$, $p_0 = 2.167 \pm 0.047$, in the first crystal.
$\rho = 65° 08' \pm 20'$, $p_0 = 2.158 \pm 0.032$, in the second.
$\rho = 64° 33' \pm 11'$, $p_0 = 2.101 \pm 0.017$, in the third.
$\rho = 64° 36' \pm 15'$, $p_0 = 2.106 \pm 0.024$, in the fourth.

Although the above quantities vary considerably, still they show clearly that the entrance of the silver in the domeykite crystal particle causes a change in its elements, the pyramids becoming steeper.

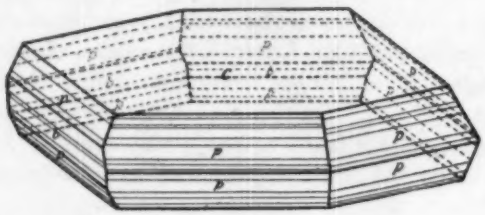


Fig. 6.

The quality of the faces of these artificial crystals was so poor that the influence of the silver in per cent. could not be determined.

Size of crystals and character of faces similar to domeykite. Of the pyramids the form p, 20 predominates, the form v, 10 occurred but once, while p, $\frac{3}{2}$ 0 was not observed. The face p, 20 frequently exhibits a slight cylindrical rounding, the axis of which runs parallel to the basal edge. Its reflexion signal is then a short light band, its bright central part indicating the position of the face. The faces are invariably striated horizontally. The different types of

crystal habit are illustrated in Figs. 6 and 7 (dimensions of crystals 0.9 × 0.9 × 0.4 mm. and 1 x 0.5 × 0.4 mm.).

The external appearance of the artificial argentodomeykite resembles that of domeykite. Its color is perhaps more nearly silver-white. The crystals tarnish easily and become iridescent.

Stibiodomeykite.

The artificial products of this mineral were not suitable for goniometric measurement. The faces were without exception uneven. An examination of the various preparations with a pocket lens revealed two different types of crystal habit—the first of them tabular with the base predominating, the other faces practically undeveloped; the second long prismatic, almost arrow-shaped, the horizontally striated pyramid faces terminating either in a short point

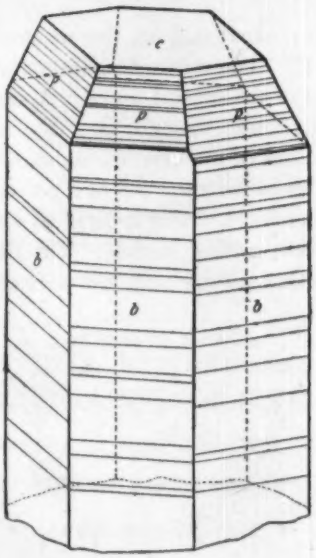


Fig. 7.

or becoming wider at the top, and resembling then an overturned bottle or inverted cone.

Color, light steel-gray. Tarnishes less readily than preceding minerals and iridescence rarely noticeable. Fracture conchoidal. H = 3–4.

Mohawkite.

The artificial crystals of mohawkite are extremely small, and not so well developed as those of the domeykite. On the goniometer their faces exhibit unclear, manifold reflexion signals which render an exact determination of the element impossible. The measurements indicated again the holohedral division of the hexagonal system.

Observed forms:

Letter:	*c*	*a*	*b*	*z*	*v*	*p*
Symbol Goldschmidt..	0	∞	∞ 0	$\frac{2}{3}$ 0	10	20
Bravais.....	0001	$11\bar{2}0$	$10\bar{1}0$	$20\bar{2}3$	$10\bar{1}1$	$20\bar{2}1$

Element:

$$f_0 = 1.001 \pm 0.008$$
$$a : c_1 = 1 : 1.501$$
$$a : c_{10} = 1 : 0.867$$

The element was computed from the mean of all usable angles. Possibie error ± 14′. The marked variation in the angles was due to the poor quality of the crystal faces. A careful search through the entire material showed that not one of the faces was perfectly even. The dimensions of the crystals are so small that the observer is unable to judge, even with the aid of a pocket lens, accurately as to the quality of the faces. The individual forms exhibit a sharp outline but an uneven, rolling surface. On the goniometer, afterwards, these characteristics are only too noticeable.

Table of Angles.

c—1′501	lg c—017656	lg a_0—006247	lg f_0—000043	a_0—1′154	f_0—1′001	(G.)

No.	*Letter*	*Symbol*	*Bravais*	ϕ	ρ	ξ_0	η_0	ξ	η	x (*Prisms*) $(x : y)$	y	d $= tg\ \rho$
				°	°	°	°	°	°	°		
1	*c*	0	0001	—	0.00	0.00	0.00	0.00	0.00	0′5773	0	0
2	*a*	∞	$11\bar{2}0$	30.00	90.00	0.00	90.00	30.00	60.00	0	∞	∞
3	*b*	∞ 0	$10\bar{1}0$	0.00	90.00	90.00	90.00	0.00	90.00	0	∞	∞
4	*z*	$\frac{2}{3}$ 0	$20\bar{2}3$	0.00	33.47	0.00	33.47	0.00	33.47	0	0′669	0′669
5	*v*	1 0	$10\bar{1}1$	0 00	45.02	0.00	45.02	0.00	45.02	0	1′001	1′001
6	*p*	2 0	$20\bar{2}1$	0.00	63.27	0.00	63.27	0.00	63.72	0	2′002	2′002

The general character and relation of the faces on the mohawkite crystals is similar to that of domeykite. The form *a*, 0.00 ∞ (11$\bar{2}$0), however, occurs more frequently and is better developed. Fig. 8 (size of crystal 0.6 × 0.3 mm.) illustrates the usual habit of the

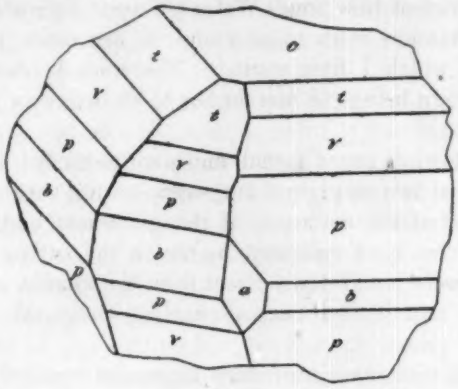


Fig. 8.

mohawkite crystals. Thin, tabular crystals like those of Fig. 2 are rare.

Luster, splendent metallic. Color, light tin-white to steel gray. Fracture conchoidal, crystal habit thick tabular to equidimensional. The crystals tarnish more readily than those of domeykite and become iridescent in brilliant, variegated hues.

LANGUAGES OF THE NEW ENGLAND ABORIGINES NEW SOUTH WALES.

BY R. H. MATHEWS, L.S.,

ASSOCIÉ ÉTRANGER SOC. D'ANTHROP. DE PARIS.

(*Read May 15, 1903.*)

SYNOPSIS.—Introductory—Orthography—The Anēwan Language—The Banbai Language—A Mystic Language—Anéwan Vocabulary.

The native tribes of New South Wales are disappearing rapidly before the advancing tide of European population, and unless some

[1] See foot-note, page 243.

person qualified for the task shall take up this highly important subject, the languages and the customs of an interesting primitive people will be lost to science.

The languages spoken by the native inhabitants of the New England district of New South Wales are quite different in vocabulary and intonation from those found in any other part of New South Wales which I have visited. Therefore I consider myself very fortunate in being the first author to report their grammatical structure.

In the following pages I shall endeavor to record and preserve the elements of two aboriginal languages, with a vocabulary of one of them. All of the materials of the grammars, and also of the vocabulary, have been collected by me in the camps of the aborigines, and were noted down direct from the mouths of the native speakers, so that I can become entirely responsible for their accuracy.

In common with other Australian languages reported by me, the Anēwan and Banbai tongues possess a double form of the first person of the dual and plural, in every part of speech subject to inflection, by means of which the person spoken to may be included or excluded. It may be stated here that I was the first author to give full details of this peculiarity in the languages of Australia,[1] although it had been observed to a certain extent in some of the islands of the Pacific Ocean, and among the Amarinds of North America. These two languages likewise contain a dual and plural number in all parts of speech.

It is hoped that these efforts of mine may prove of some value, by enabling philologists to compare the native tongues of Australian tribes, not only among themselves, but with other languages in the islands of Polynesia, Melanesia, and various parts of the Pacific Ocean, as well as with the speech of other primitive tribes in different parts of the world.

The space at my disposal in the PROCEEDINGS of this Society render it necessary to describe only the leading elements of the languages dealt with.

ORTHOGRAPHY.

The system of orthoepy adopted is that which is recommended by the Royal Geographical Society of England, but a few addi-

[1] "The Gundungurra Language," PROC. AMER. PHIL. SOC., Vol. xl, p. 140.

tional forms of spelling have been incorporated, to meet the requirements of the Australian pronunciation, as follows:

As far as possible, vowels are unmarked, but in some instances the long sound of *a*, *e* and *u* are indicated thus, ā, ē, ū. In a few cases the short sound of *u* has been marked thus, ŭ.

G is hard in all cases. *R* has a rough, trilled sound, as in the English word "hurrah!" *W* always commences a syllable or word.

Ng at the beginning of a word or syllable has a peculiar nasal sound. At the end of a syllable or word it has substantially the sound of *ng* in the English word "sing."

The sound of the Spanish ñ is frequent; at the beginning of a word or syllable I have given it as *ny*, but when terminating a word the Spanish ñ is used. *Y* at the beginning of a word has its ordinary consonant value.

Dh is pronounced nearly as *th* in the English word "that," with a slight sound of *d* preceding it. *Nh* has also nearly the sound of *th* in "that," but with a slight initial sound of the *n*.

T is interchangeable with *d*; *p* with *b*; and *g* with *k*.

Ty and *dy* at the commencement of a word or syllable have nearly the sound of the English *j*, or the Spanish *ch*; thus, *dya* or *tya* closely resemble *ja* or *cha*. At the end of a word or syllable *ty* is sounded as one letter, closely approaching the *tch* in the English word "catch," but omitting the final hissing sound.

In all cases where there is a double consonant, each letter is enunciated.

The Anewan Language.

The remnants of the Anēwan tribe are scattered over the southern half of what is known as the "table-land" of New England, including Macdonald river, Walcha, Uralla, Bendemeer, Armidale, Hillgrove and other places.

ARTICLES.

The indefinite article, *a*, is not represented, but the demonstrative pronouns, in their numerous modifications, supply the place of the definite article, as "this man," "that woman," "yonder hill." The English adverb, *here*, in its several native forms, is frequently treated as a demonstrative, and is then also a substitute for the definite article.

NOUNS.

Nouns have number, gender and case.

Number.—There are three numbers—singular, dual and plural. Kana, a crow. Kanaburala, a pair of crows. Kananyeta, several or many crows.

Gender.—Gender in the human family is denoted by different words. Tana, a man. Kettyura, a woman. Romunna, a boy. Kĕmika or nganda, a girl. Kwanga, a child of either sex.

Among animals gender is distinguished by using words signifying "male" and "female." Pwēla, an opossum. Pwēla rula, a male opossum. Pwēla imbarra, female opossum.

Case.—The principal cases are the nominative, causative, instrumental, possessive, accusative, dative and ablative.

Nominative: This case simply names the subject, as imboanda, a kangaroo; naia, a yamstick, without any change in the noun.

Causative: When a transitive verb is used the noun takes a suffix, as Tananda imboanda nyuna, a man a kangaroo is beating. Kettyuranda pwēla nyuna, a woman an opossum is beating.

Instrumental: This takes the same suffix as the causative. Kettyuranda tana nyuna naianda, a woman a man is beating with a yamstick. Tananda imboanda nyūmbina arkananda, a man a kangaroo hit with a boomerang.

Possessive: Tanango arkana, a man's boomerang. Kettyurango naia, a woman's yamstick.

Accusative: This is the same as the nominative.

Dative: Rullagu, to a camp.

Ablative: Rullŭnge, from a camp.

It should be mentioned that in all the expressions illustrating the several cases, both in the Anĕwan and Banbai languages, the demonstrative pronouns are omitted, for the two-fold purpose of saving space and of avoiding confusion by introducing any more words than are really necessary to show the declension. For example, where I have given "man kangaroo hit with boomerang" would be fully expressed by the native thus: "Man this-on-my-right kangaroo yonder-in-front boomerang struck-with," or as the subject might require.

These remarks apply to every example of aboriginal sentences throughout both the languages dealt with in this article.

ADJECTIVES.

Adjectives succeed the nouns they qualify, and take the same inflections for number and case.

Tana birkungirra, a man large.

Tanango birkungirrango arkana, a large man's boomerang.

Tananda birkungirranda kwanga nyuna, a large man is beating a child.

It is not necessary to give examples of the other cases.

Comparison of adjectives is effected by two positive statements, such as, This is good—that is bad; runyerra indya—irrunga indyunda.

PRONOUNS.

Pronouns have three numbers, with inclusive and exclusive forms in the first person of the dual and plural. The following table exhibits the nominative pronouns:

Singular	1st Person	I	Yukka
	2d "	Thou	Indyukka
	3d "	He	Gambaua
Dual	1st Person	We, incl.,	Tēka
		We, excl.,	Tāla
	2d "	You	Twukka
	3d "	They	Takana
Plural	1st Person	We, incl.,	Nyukka
		We, excl.,	Nāla
	2d "	You	Audilla
	3d "	They	Nalena

The possessive and objective pronouns are as under:

Singular.

1st Person	Mine	Yinga	Me	Enna
2d "	Thine	Nyunga	Thee	Nunya
3d "	His	Onning	Him	Onna
1st Person	Ours, inc.,	Tenyunga	Us, incl.,	Tenya
	Ours, excl.,	Tambiga	Us, excl.,	Tuanya
2d "	Yours	Twanyung	You	
3d "	Theirs	Lambiga	Them	Walanya
1st Person	Ours, incl.,	Nyambiga	Us, incl.,	Nanyabura
	Ours, excl.,	Nyanyambiga	Us, excl.,	Nanyumbinga
2d "	Yours	Nuka	You	Audumbinga
3d "	Theirs	Nambiga	Them	Nanya

There are forms of the pronouns meaning "away from me," "towards me," etc., which must be passed over for want of space.

Interrogatives: Who, anunga. What, nyanga. What for, nyangabura.

Demonstratives: This, indya. That, indyunda. The demonstratives are numerous, and of various forms, frequently taking the place of pronouns of the third person in the singular, dual and plural. This accounts for the great diversity of the third personal pronouns, which have little or no etymological connection with the others.

The demonstratives in this language, by the combination of simple root-words, can be made to indicate position, direction, distance, movement, possession, number, person and size. If space permitted, I could show tables of these demonstratives which would be most important for comparative purposes. This applies also to the Banbai demonstratives.

VERBS.

Verbs have the singular, dual and plural numbers, with the usual tenses and moods. There is a form of the verb for each tense, which remains constant through all the persons and numbers of that tense. Any person and number can be expressed by using the required pronoun from the table given in the foregoing page.

Following is a short conjugation of the verb Nyuka, "to beat or strike."

Indicative Mood—Present Tense.

Singular	1st Person.....I beat		Yukka nyuna
	2d " .....Thou beatest		Indyukka nyuna
	3d " .....He beats		Gambaua nyuna

and so on through the dual and plural.

Past Tense.

Singular.....	1st Person.....I beat	Yukka nyumbina

Future Tense.

Singular.....	1st Person.....I will beat	Yukka nyumarala

Imperative Mood.

Beat, nyumera	Beat not, yinna nyumera

Conditional Mood.

Perhaps I will beat	Yukka neta nyumarala

Reflexive.

Present..I beat myself	Yukka nyugatina
Past ....I beat myself	Yukka nyugatimbina
Future ..I will beat myself	Yukka nyugatila

Reciprocal.

Dual....We, exclusive, are beating each other,	Tāla nyutaka
Plural...We, exclusive, are beating each other,	Nāla nyutaka

ADVERBS.

The following are a few of the more commonly used adverbs:

Yes, ngeh. No, apala. Today, lunna. Tomorrow, yūn. Soon, lanabura. By and bye, loka. Long ago, toangga. Now, ilan. Recently, irrandya.

How, thanggana. Where, renya. How many, thambula. Here, āwa. There, gamba. The two last are frequently used as demonstratives.

PREPOSITIONS.

In the rear, yanda. In front, gattanda. Around, lunggai. In the middle, umūnda. Up, dapai. Down, irrakirran. Between, ilkongga.

CONJUNCTIONS.

The general absence of conjunctions is attributable to the numerous modifications of the different parts of speech, by means of which sentences are brought together without the help of connecting words.

INTERJECTIONS AND EXCLAMATIONS.

These parts of speech are not numerous.

NUMERALS.

One, nyoanda. Two, tuala.

The Banbai Language.

The aboriginal tribes speaking this language adjoin the Anéwan community on the north, and are located at Guyra, Ben-Lomond, Wollomombi and Kookarabooka.

NOUNS.

Number.—There is no special declension for number, but the noun is followed by words signifying two or several.

Ginggēr bulabulari, kangaroos two.

Ginggēr girrawa, kangaroos several.

Gender.—Man, thaimburra. Woman, burranyen. Boy, bodyerra. Girl, dillanggan. The sex of animals is denoted by words meaning "male" and "female" respectively, placed after the creature's name, as, Margan dyillawara, a buck wallaby. Margan kandura, a doe wallaby. Among birds, boro means a cock, and ngapara, a hen.

Case.—There are the nominative, causative, instrumental, possessive, accusative, dative and ablative cases.

Nominative: Tua, a boomerang. Kunnai, a yamstick. Wandyi, a dog.

Causative: Ginggēru nganya bittang, a kangaroo me scratched. Burranyendu nganya buang, a woman me struck.

Instrumental: Thaimburradu nganya bindaimang tuandu, a man at me threw a boomerang.

Possessive: Burranyengu kunnai, a woman's yamstick. Thaimburrangu tua, a man's boomerang.

In the Gundungurra, and in several other aboriginal languages of New South Wales and Victoria, the article possessed takes a suffix, as well as the possessor. For example, warrangan means a boomerang, and murriñ a man, but "a man's boomerang" must be expressed, Murrin-*gu* warrangan-*gung*. Until reported by me,[1] this peculiarity of a double suffix in the genitive case of Australian nouns had not been observed by any previous author.

Dative: Nguralami, to a camp.

Ablative: Nguranga, from a camp.

Accusative: This is the same as the nominative.

ADJECTIVES.

Adjectives take the same inflections as the nouns which they qualify.

Thaimburra burwai, a man large.

Thaimburradu burwaidu nganya buang, a man large me struck.

Thaimburrangu burwaigu tua, a large man's boomerang.

[1] "The Gundungurra Language," PROC. AMER. PHIL. SOC., Vol. xl, p. 143.

Comparison: Nyam dhurrui—nyam yōnggo; this is good—that is bad. Nyam dhurruiūnba, this is very good.

PRONOUNS.

Pronouns have the nominative, possessive and objective cases, as in the subjoined tables. There are two forms in the first person of the dual and plural—one in which the person or persons addressed are included with the speaker, and another in which they are exclusive of the speaker. The following is a list of the pronouns in the nominative case:

Singular	1st Person.....I		Ngaia
	2d " .....Thou		Nginda
	3d " .....He		Ngurrung
Dual	1st Person...	We, incl.,	Ngulli
		We, excl.,	Ngulligai
	2d " ...	You	Bulala
	3d " ...	They	Bulagai
Plural	1st Person...	We, incl.,	Nyeūlla
		We, excl.,	Nyeūllagai
	2d " ...	You	Nguddyilindya
	3d " ...	They	Yangbēndu

The possessive and objective forms of the pronouns are exhibited in the following table:

Singular.

1st Person.....Mine	Ngunyo	Me	Nganya
2d " .....Thine	Nginnu	Thee	Ngēna
3d " .....His	Gurragunga	Him	Nyam

Dual.

1st Person ..	Ours, incl.,	Ngullimba	Us, incl.,	Ngullinya
	Ours, excl.,	Ngullimbagai	Us, excl.,	Ngullinyagai
2d " ...	Yours	Bullamba	You	Bulanya
3d " ...	Theirs	Bullambagai	Them	Bulanyagai

Plural.

1st Person ..	Ours, incl.,	Ngeūmba	Us, incl.,	Ngeanya
	Ours, excl.,	Ngeumbagai	Us, excl.,	Ngeanyagai
2d " ...	Yours	Nguddyimba	You	Nguddyinninya
3d " ...	Theirs	Ittyāran	Them	Ittyārambēn

There are also forms meaning "with me," nganyumbulla. Ngaia, as in the table, is used with an intransitive verb, as, ngaia nganggi, I sit; but when a transitive verb is used, the pronoun is changed to ngatya, as, Ngatya bōnggi, I beat. These rules apply to the other persons and numbers. Other forms of the pronouns are omitted for want of space.

Interrogative pronouns: Who, wuttanya. Whom belonging to, wuttanyannin. What, minya. How many, minya-minya.

Demonstrative pronouns: This, nyam. That, mumum. These are frequently used as adverbs, and they mean "here" and "there."

VERBS.

The rules for the conjugation of verbs are similar to those of the Anēwan language. An example in the singular number of each tense will be sufficient:

Indicative Mood—Present Tense.

Singular	1st Person.....I beat		Ngatya bōnggi
	2d " .....Thou beatest		Nginda bōnggi
	3d " .....He beats		Ngurrung bōnggi

Past Tense.

Singular.....	1st Person.....I beat		Ngatya boang

Future Tense.

Singular.....	1st Person.....I will beat		Ngatya bōanggo

The imperative, conditional, reflexive and reciprocal forms of the verb will be passed over for want of space.

ADVERBS.

Yes, nge. No, wunā. Today or now, gillu. Tomorrow, gurlau. Soon, gurubilli. By and bye, kangā. Long ago, dhullūmba. Yesterday, nyukkumba. Certainly, yare. How, dyirrung. Perhaps, dyirraugam. Where, dyota. How many, minya-minya. Here, nyam. There, mundyaba. Yonder, mungga-munggara. Marēda, far away. Close to speaker, tulbaia.

The adverbs "here" and "there" are often used as demonstrative pronouns, and have the same meaning as "this" and "that."

PREPOSITIONS.

In front, munggara. In rear, wallungga. Between, pimita. On the other side, kawatadyula. On this side, ilāmgidda. Up, kaba. Down, warri. Around, kokari.

Conjunctions and interjections are omitted.

NUMERALS.

One, kurrukun. Two, bulari.

A Mystic or Secret Language.

Before concluding this short article on the speech of the Australian aborigines, I wish to refer to a secret language, used by the men at the ceremonies of initiation, but which is never spoken in the presence of women, or in the presence of those youths who have not yet entered upon the prescribed course of initiation. Whilst the novitiates are away in the bush in charge of the elders of the tribe, they are taught a mystic name for surrounding objects of every-day life, for animals, for parts of the human body, and short sentences of general utility. This language is different in different tribes.

I was the first author to draw attention to this mystic tongue,[1] and during the past year I contributed to the Royal Society of New South Wales some vocabularies of the secret languages of the Kurnu[2] and other Australian tribes. I consider my discovery of this secret form of speech is of great linguistic importance, and invite my readers to peruse the vocabularies referred to.

In connection with this subject it may be mentioned that in 1901 I contributed an article to the Royal Geographical Society of Queensland, on some "Aboriginal Songs at Initiation Ceremonies,"[3] in which I published several sacred chants in the secret tongue, which are the first songs of the kind ever set to music.

Vocabulary of Anewan Words.

The following vocabulary, containing about 210 of the most important words in general use by the Anēwan tribes, has been prepared by me from notes taken in the camps of the aborigines.

[1] *Journ. Anthrop. Inst.*, London, Vol. xxv, p. 310.
[2] *Journ. Roy. Soc. N. S. Wales*, Vol. xxxvi, pp. 157–160.
[3] *Queensland Geographical Journal*, Vol. xvii, pp. 61–63.

Every word was carefully written down by myself from the mouths of the natives.

In a communication to the Royal Society of Victoria in the year 1896,[1] I gave a comprehensive description of the initiation ceremonies of the Anēwan, Banbai and other tribes. Again in 1897, I contributed a paper to the Royal Society of New South Wales,[2] in which I described the Anēwan laws of marriage and descent, with lists of their *totems*. On account of the two articles referred to, it has not now been thought necessary to repeat the subjects therein dealt with.

English.	*Anēwan.*
Man	tana
Boy	rumunna
Elder brother	irkōmba
Younger brother	ilpaminda
Father	pēta
Woman	kettyura
Girl	kemika
Elder sister	pauana
Younger sister	paua
Mother	irrapella
Child of either sex	kwanga
The Human Body.	
Head	kwulla
Forehead	tui
Hair of head	rella
Beard	nutyina
Eye	ila
Nose	nyanba
Jaw	dhanda
Ear	nakuna
Teeth	yella
Tongue	tŭnda
Navel	dyikanga
Back	twila
Arm	kyŭnda
Shoulder	irringala
Elbow	indina
Hand	nyella
Calf of leg	yula
Thigh	illanba
Knee	gwunba
Foot	nyalla
Heel	nungan
Blood	gwianba
Woman's breasts	ipinda
Fat	pyenna
Skin	twunda
Penis	duna
Testicles	ilwundandha
Semen	bungan
Copulation	bungadala
Masturbation	bungalulamun

[1] "The Bŭrbŭng of the New England Tribes," *Proc. Roy. Soc. Victoria*, Vol ix, N. S., pp. 120–136.

[2] "The Totemic Divisions of Australian Tribes," *Journ. Roy. Soc. N.S. Wales*, Vol. xxxi, pp. 168–170.

English.	*Anēwan.*
Venereal	tharpunda
Anus	būlla
Excrement	ngunba
Urine	itirra

Natural Surroundings.

Sun	nura
Moon	ternda
Stars	ikina
Sky	rūnbinna
Thunder	lāmutika
Lightning	kimmitta
Rain	yūnggara
Fog	ngatta
Snow	ikana
Frost	lala
Hail	arrepanna
Water	ukūnda
The ground	kyuna
Stones	rola
Sand	raikana
Darkness	illona
Coldness	inganna
Fire	inba
Smoke	rutta
Night	lōnna
Food (flesh)	kara
Food (vegetable)	kyaia
Honey	irrōta
Hill	kuta
Watercourse	retta
Any tree	dulla
Leaves of trees	indora
Path	kurra
Shadow	tonba
Summer	ilkaiwa
Winter	tyerwanba

English.	*Anēwan.*
Rainbow	rumira
Large flat rock	lara
Camp	rulla

Mammals.

Kangaroo	imboanda
Porcūpine	iwutta
Wild-dog	irritanga
Opossum	pwela
Flying-fox	ramana
Kangaroo-rat	bara
Native-bear	lauanha
Wallaroo	lumulla
Bandicoot	imbunga
Ring-tail opossum	aunda
Native-cat	kyura
Wallaby	kyatta
Tiger-cat	yāra
Bat	lyunganda

Birds.

Birds collectively	pillang
Emu	runda
Eagle-hawk	lambara
Black-duck	rungara
Pelican	wuyara
Laughing jackass	rokala
Crow	kana
Swan	dyuwula
Native-companion	rualgunda
White cockatoo	ērpatha
Black cockatoo	wellara
Common magpie	imbota
Plover	tharringga

English.	*Anēwan.*
Curlew	rilwinnu
Brown-hawk	ōwara
Parrokeet	imbanga
Mopoke	ūrkūng
Fishes.	
Perch	indanga
Jewfish	lyūnda
Codfish	guyu, *or* ruta
Sprat	birran
Eel	indhurra
Reptiles.	
Black iguana	rutyala
Water iguana	nhawala
Ground iguana	tyunda
Spotted iguana	laipara
Jew-lizard	nura
Snakes collectively	yenda
Death-adder	minda
Rock-lizard	roppung
Turtle	yiwang
Stinking-turtle	werra
Big frog	imbottonga
Carpet-snake	imbiāla
Sleepy lizard	pwoggana
Invertebrates.	
Bee	ronnang
Locust	warra
Centipede	engara
Louse	irrakanba
Nits of lice	minna
House-fly	rulunga
Spider	ālman
Mosquito	irwala

English.	*Anēwan.*
Bulldog ant (red)	thanda
Bulldog ant (black)	oppunga
Scorpion	imbūnda
Crab	thambanna
Trees and Plants.	
Mountain ash	o-inba
Kurrajong	nùnggutta
Ironbark	girranba
Stringy bark	indwarra
Wattle	luna
Grass-tree	dunburra
Peppermint	nēwurra
Apple-tree	tūnba
Gum-tree	orrulla
Scrub-gum-tree	bikkara
Pine	wungulla
White box	yina
Reeds	moanda
Forest oak	rēwilla
Cherry-tree	poara
Jeebung	lwainda
Weapons, etc.	
War spear	kyenba
Hunting spear	anbelang
Jagged spear	mumberiñ
Spear shield	indūta
Club shield	bekang
Club	raipella
Spear thrower	womur
Boomerang	arkana
Tomahawk	mukung
Fighting-hook	lēnyang
Nulla-nulla	rularokara
Koolamin	tilla
Net bag	loia

English.	*Anēwan.*
Yamstick	naia
Stone knife	imbōnda
Adjectives.	
Large	birkingirra
Small	latherana
Good	rōnyerra
Bad	irrūnga
Hungry	imbyura
Thirsty	ambia
Quick	ngunna
Slow	numbadia
Afraid	no-aran
Angry	anagana
Greedy	myūna
Verbs.	
Eat	mēka
Drink	imbekka
Sit	nina
Speak	oidekka
Walk	nadiga
Run	nuppanati
Break	wammin
Give	unumbia
Sing	peka
Weep	twaka
Steal	nomekka
Bite	irruttela
Catch	anamarai
Climb	irrukka
Hear	nugguna
Laugh	indeka
Scratch	nirmatin
See	aikunna
Dance	thekinna
Swim	imbwiana
Stand	rāgya
Throw	imbia
Pretend	twandyingan
Swallow	pwika

ON SOME NAMES (CHIEFLY LINNEAN) OF ANIMALS AND PLANTS ERRONEOUSLY PAIRED IN SYNONYMY.

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It is well known that a great many new genera have been made for the old Linnean species. One of the chief creators of generic names was Lamarck, the great naturalist. After him a large number of authors have proposed many new genera for the Linnean species. The same is true, also, for many species proposed by ancient authors that have been related in synonymy, when a new genus has been created for the same species.

In my note, "Intornorno ad alcuni nomi di conchiglie linneane," published in the *Bulletin* of the Italian Malacological Society (Vol. x, 1884), I have proposed to retain the original Linnean names for

the species, though this may have been chosen to denote the genus. For instance, the name of *Mya vulsella* L. (as a new genus has been created) has been changed in *Vulsella lingulata*. The name of *Ostrea malleus* L. has been changed in *Malleus vulgaris* Lamk. I have proposed in similar cases to retain the original name of the species, which I believe is the more correct. So I have proposed to call these species *Vulsella vulsella* (L.), *Malleus malleus* (L.).

My proposition has been accepted by many malacologists. Indeed now instead of *Plicatula ramosa* Lamk. (=*Sponotilus plicatus* L.), it is better to employ the name *Plicatula plicata* (L.) sp. Instead of *Lima squamosa* Lamk, (=*Ostrea lima* L.) the name of *Lima lima* (L.) sp.; instead of *Hippopus maculatus* Lamk, (=*Ostrea hippopus* (L.)) the name of *Hippopus hippopus* (L.) sp., etc.

I think that this modification might be conveniently adopted also for plants as well as animals. I believe, for instance, it is much better to say *Tymnus tymnus* than *Scomber tymnus* or *Tymnus vulgaris*. For the same reason I believe it to be much more correct to say *Malus malus* instead of *Pyrus malus* or *Malus communis*.

What I have said for the names of Linné, is also applicable to the names of other authors which have been changed, because recent authors have chosen the name of the species as a generic name.

I call the attention of zoologists and botanists to this interesting innovation. I hope that it will be adopted for plants and for all animals, as it has been for the mollusks.